Climate Change:

From Science to Solutions

Impact of Climate Change on the Great Lakes Ecosystem

July 30, 2008.

GREAT LAKES BASIN

Rosina Bierbaum, Dean and Professor

A NOAA Science Needs Assessment Workshop

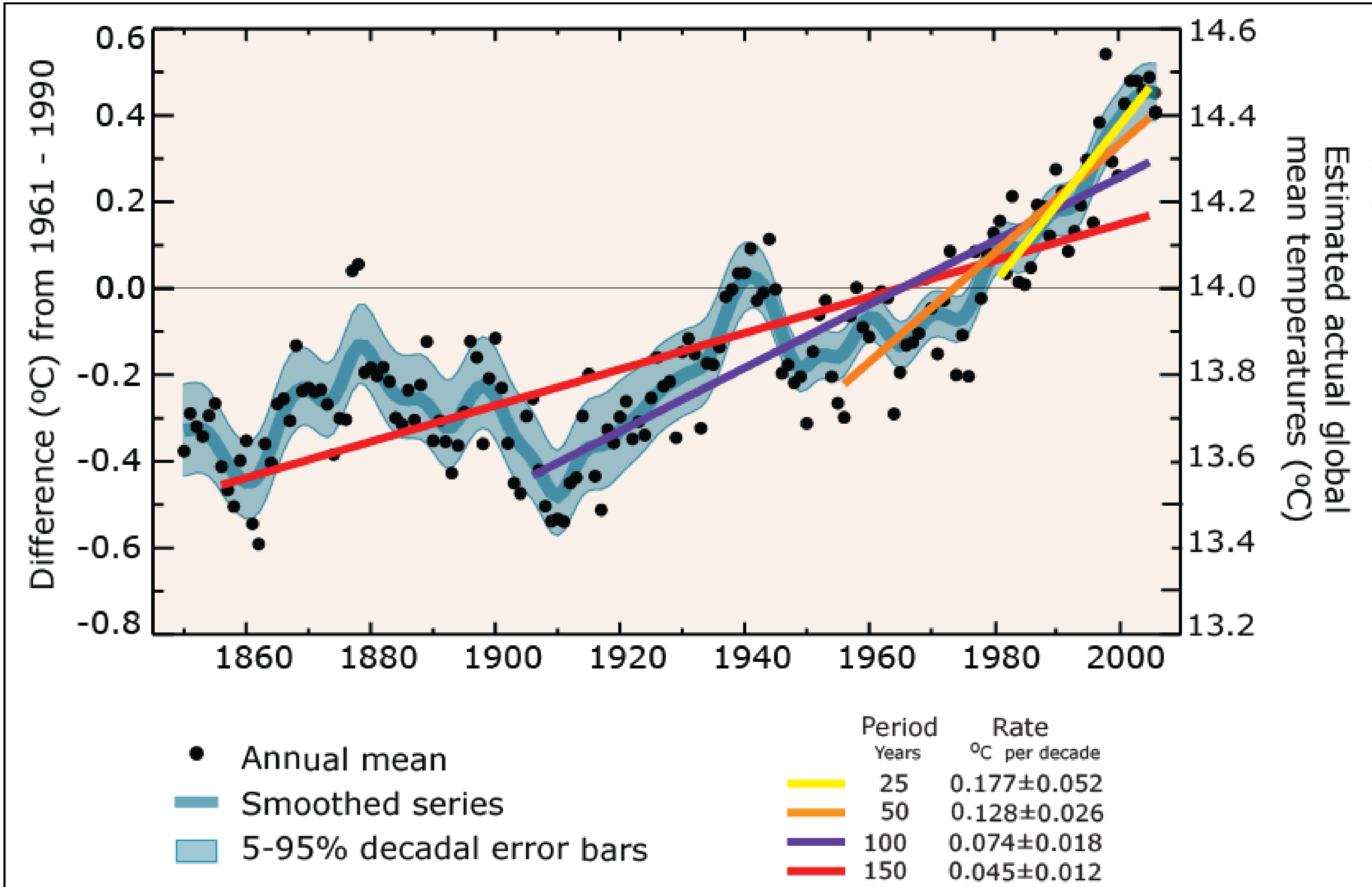
to Meet Emerging Challenges

Natural Resources and Environment
University of Michigan

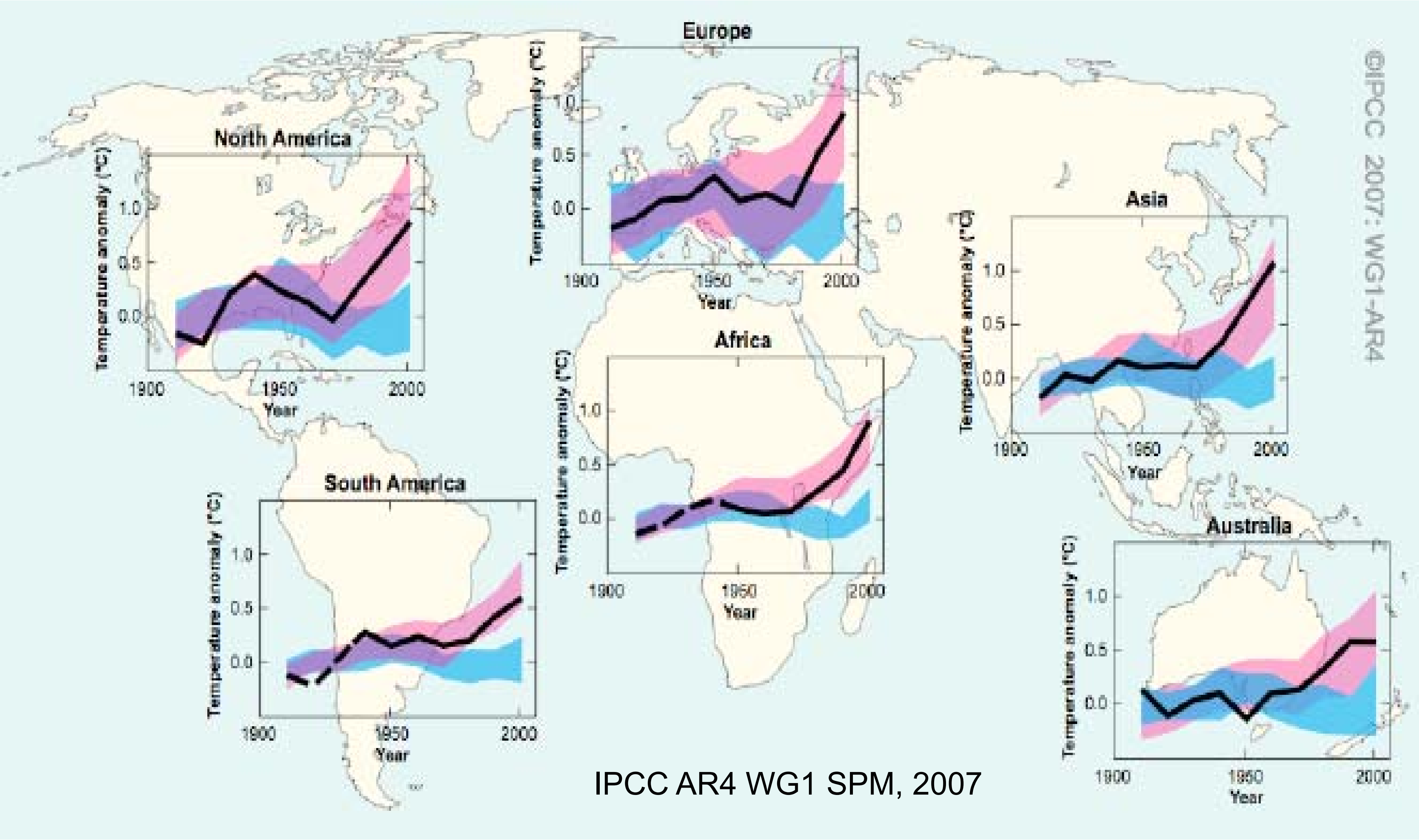
Conclusions of the talk

- Climate change threatens the attainment of the Millennium Development Goals
- Adaptation & mitigation are BOTH necessary: adaptation is not a copout, it’s a necessity
- There may be physical, ecological and societal ‘tipping points’ in store
- Adaptation research & options to cope are nascent
- A rich interdisciplinary research, planning and management agenda must be tackled now—and the Federal and academic communities are not poised or funded sufficiently to do so

Global average temperature is rising at an accelerating rate



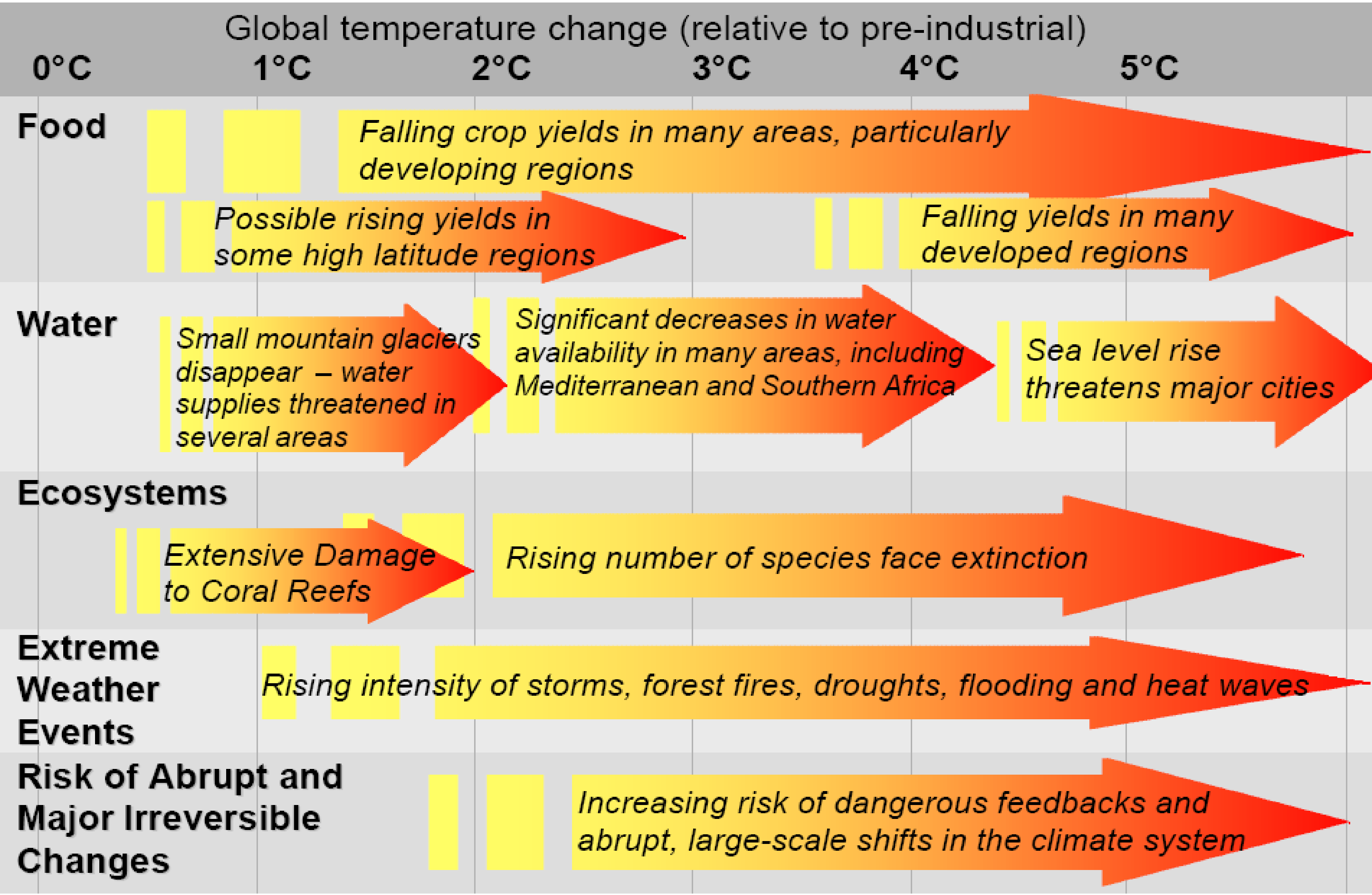
Computer models match observed ΔT on all continents



IPCC AR4 WG1 SPM, 2007

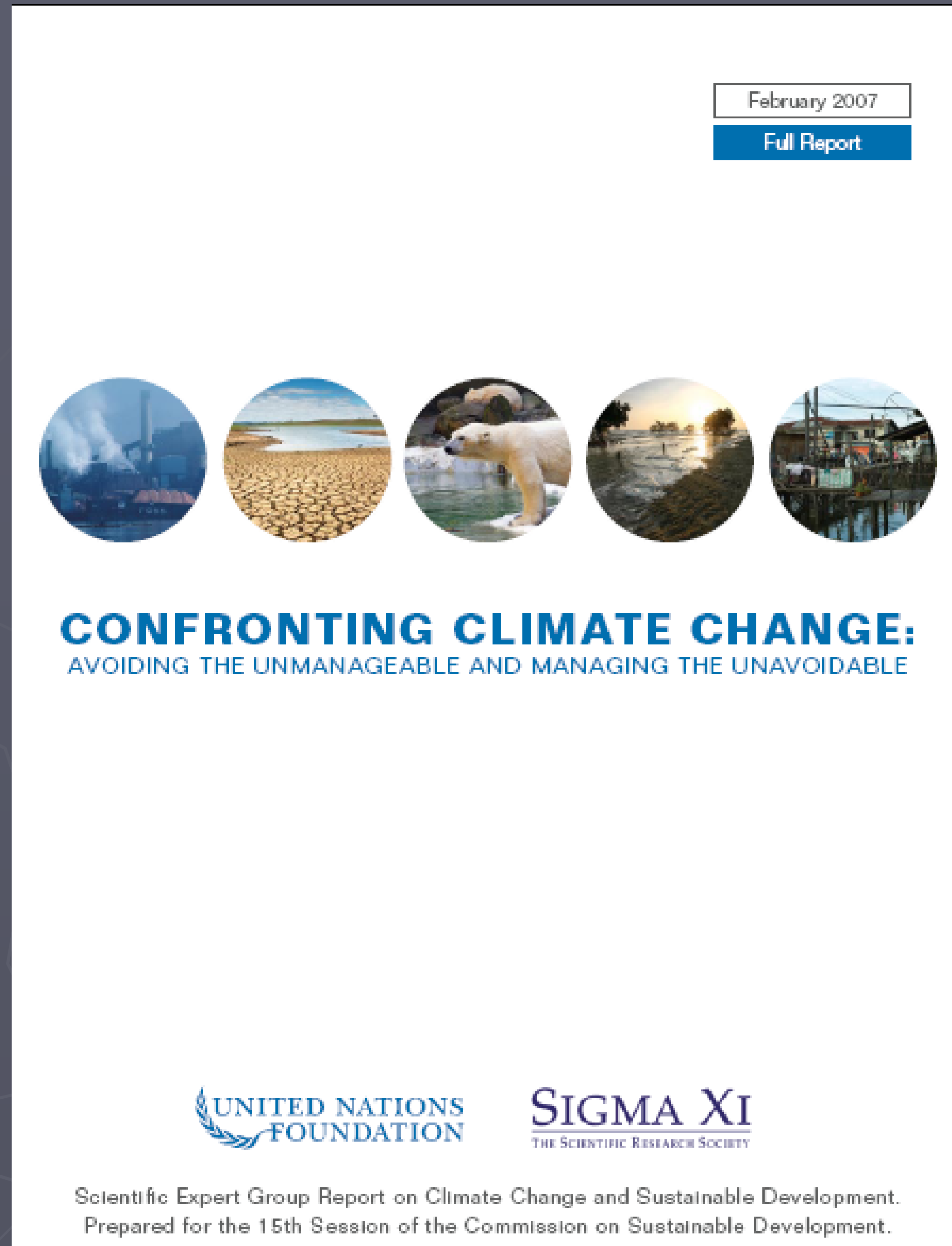
Black lines are decadally averaged observations. Blue bands are computer models with natural forcings only. Pink bands are computer models with human + natural forcings.

Projected Impacts of Climate Change



The Millennium Development Goals

1. Eradicate Extreme Poverty and Hunger--
   Halve, between 1990 and 2015, the proportion of people living on less than $1/day and the proportion of people suffering from hunger.
2. Achieve Universal Primary Education
3. Promote Gender Equality & Empower Women
4. Reduce Child Mortality--**Reduce by 2/3, between 1990 and 2015, the under-5 mortality rate.**
5. Improve Maternal Health--**Reduce by 3/4, between 1990 and 2015, the maternal mortality rate**
6. Combat HIV/AIDS, malaria and other diseases--
   By 2015 have halted and begun to reverse the spread of HIV aids and the incidence of malaria and other major diseases.
7. Ensure Environmental Sustainability
8. Develop a global partnership for Development


February 2007

Full Report

CONFRONTING CLIMATE CHANGE:

AVOIDING THE UNMANAGEABLE AND MANAGING THE UNAVOIDABLE

UNITED NATIONS FOUNDATION

SIGMA XI

THE SCIENTIFIC RESEARCH SOCIETY

Scientific Expert Group Report on Climate Change and Sustainable Development.
Prepared for the 15th Session of the Commission on Sustainable Development.

http://www.unfoundation.org/files/pdf/2007/SEG_Report.pdf

A world vulnerable to Climate Change may not achieve the MDGs

- **Most impacts are will be negative, especially for the poorest, most vulnerable nations. Tens of billions of dollars of ODA are at risk.**
- **All sectors in all regions of the globe will be challenged**
- **Institutions are ill-prepared to manage climate change impacts.**
- **Both Mitigation and Adaptation are needed.**
- **Responding to Climate Change can & must advance the MDGs**

– *Clean & affordable energy supplies are essential for achievement of MDGs*

– *Sustainable land-use policies are vital for agricultural and forestry*


Vulnerabilities & Consequences of Climate Change
Agriculture
Forests
Water
Coastal
Ecosystems
Health
Communities
Energy
Commerce
Atmosphere (Greenhouse Gases)
Temperature
Precipitation
Sea Level
Glacial Melting
Extreme Events

Agriculture

- Threatening Food Supply
- Crop Yields
- Irrigation Demands

Exacerbation of Existing Problems

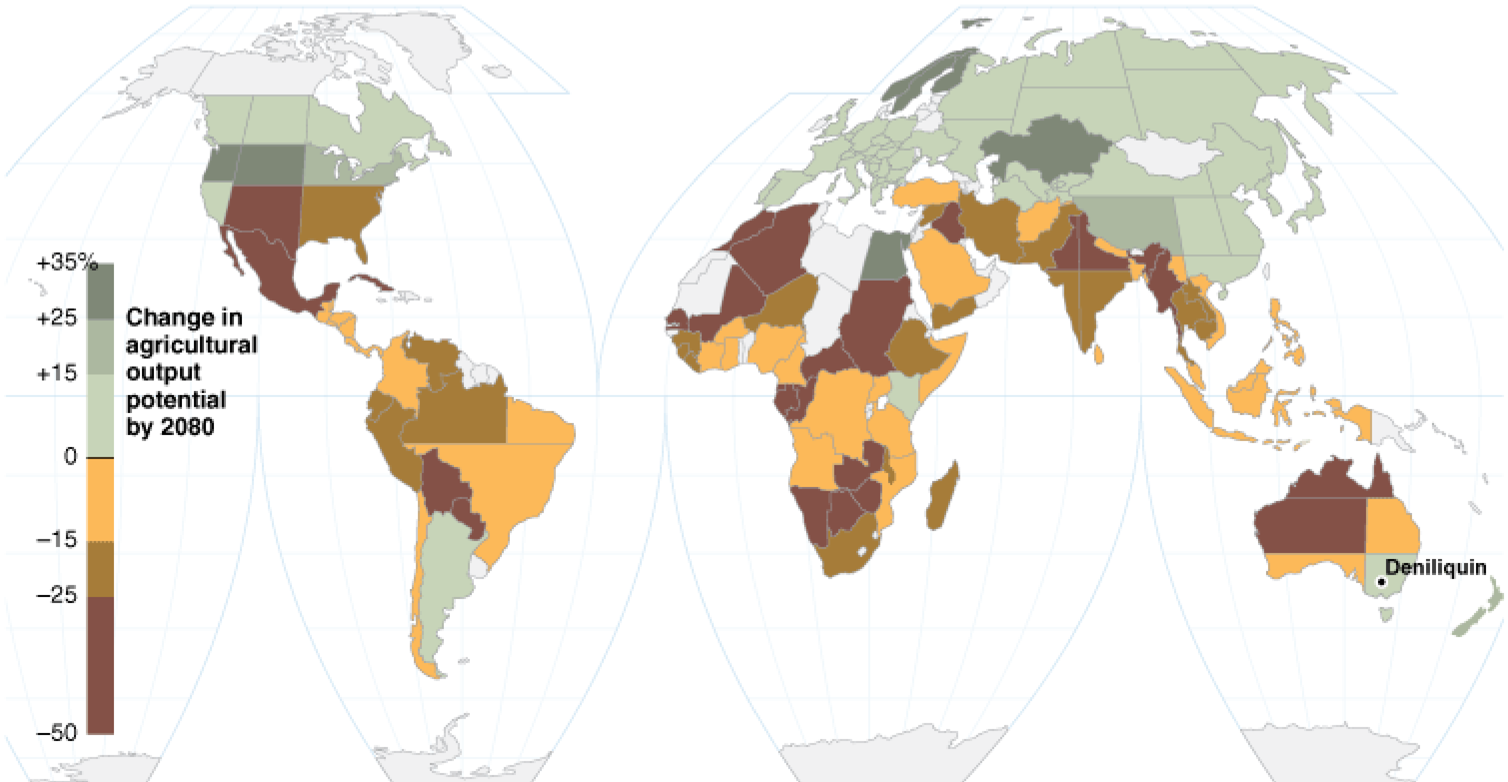
Agriculture in the Midwest

- Benefits:
  - warmer temperatures, longer growing season, CO_2 fertilization

- Constraints:
  - declining soil moisture, higher ozone, more pests, storms & floods during planting and harvesting, extreme heat, invasives?

Farming in a Warmer World

Crop forecasts show that some countries farther from the Equator could benefit from a warmer world, but others would be worse off by 2080 if global warming were to proceed unchecked. Long-range forecasts vary widely; the following is a synthesis of available forecasts by country or region.

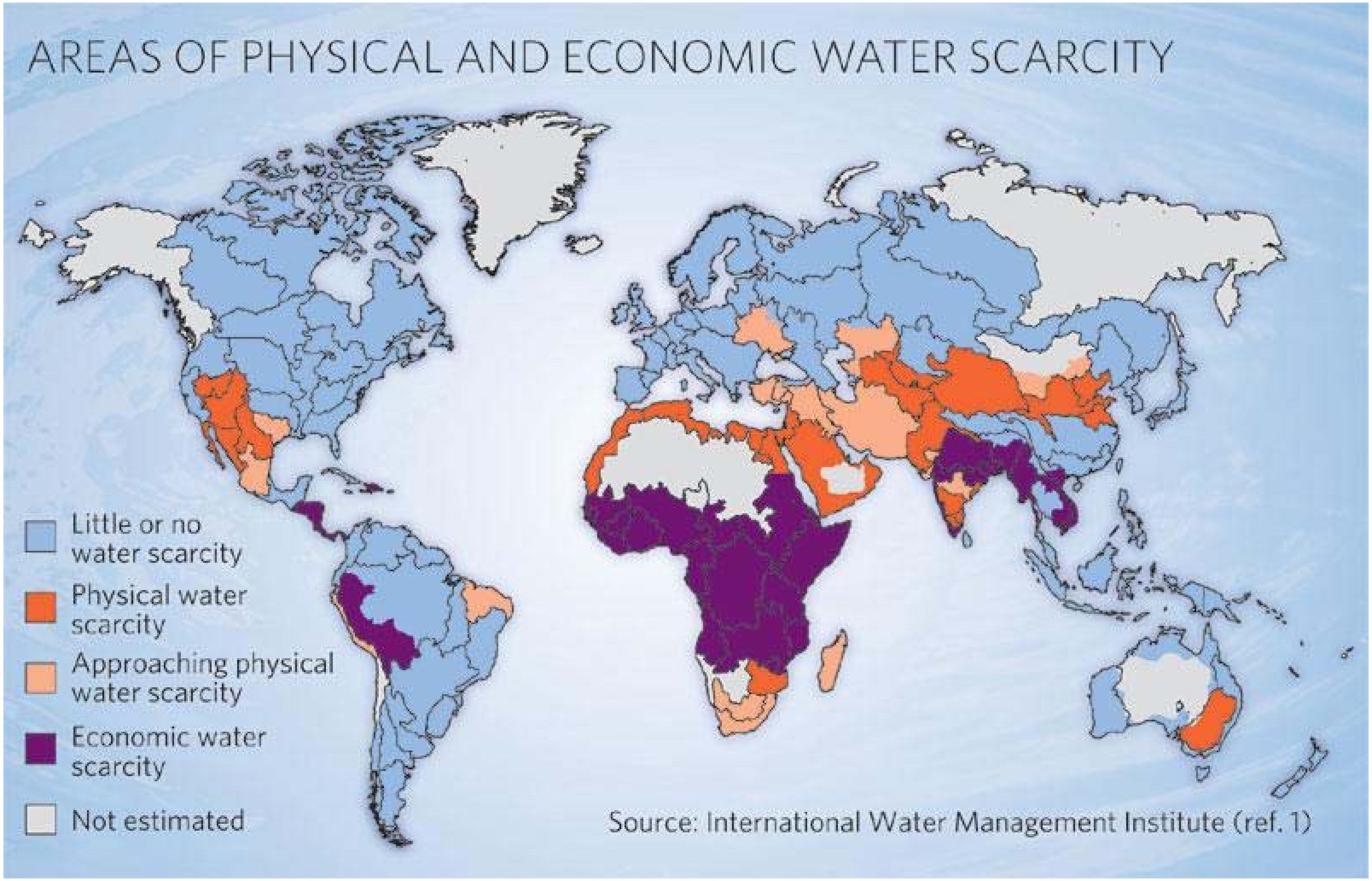


Note: These figures assume that crops grow faster because of higher levels of carbon dioxide in the air. But some scientists say that the actual effects of global warming could be worse than shown here, because the benefits of extra carbon dioxide may not appear if crops lack proper rainfall, proper soil and clean air.

Source: "Global Warming and Agriculture: Impact Estimates by Country," by William R. Cline, Peterson Institute, 2007.

Water

- Supply
- Quality
- Competition

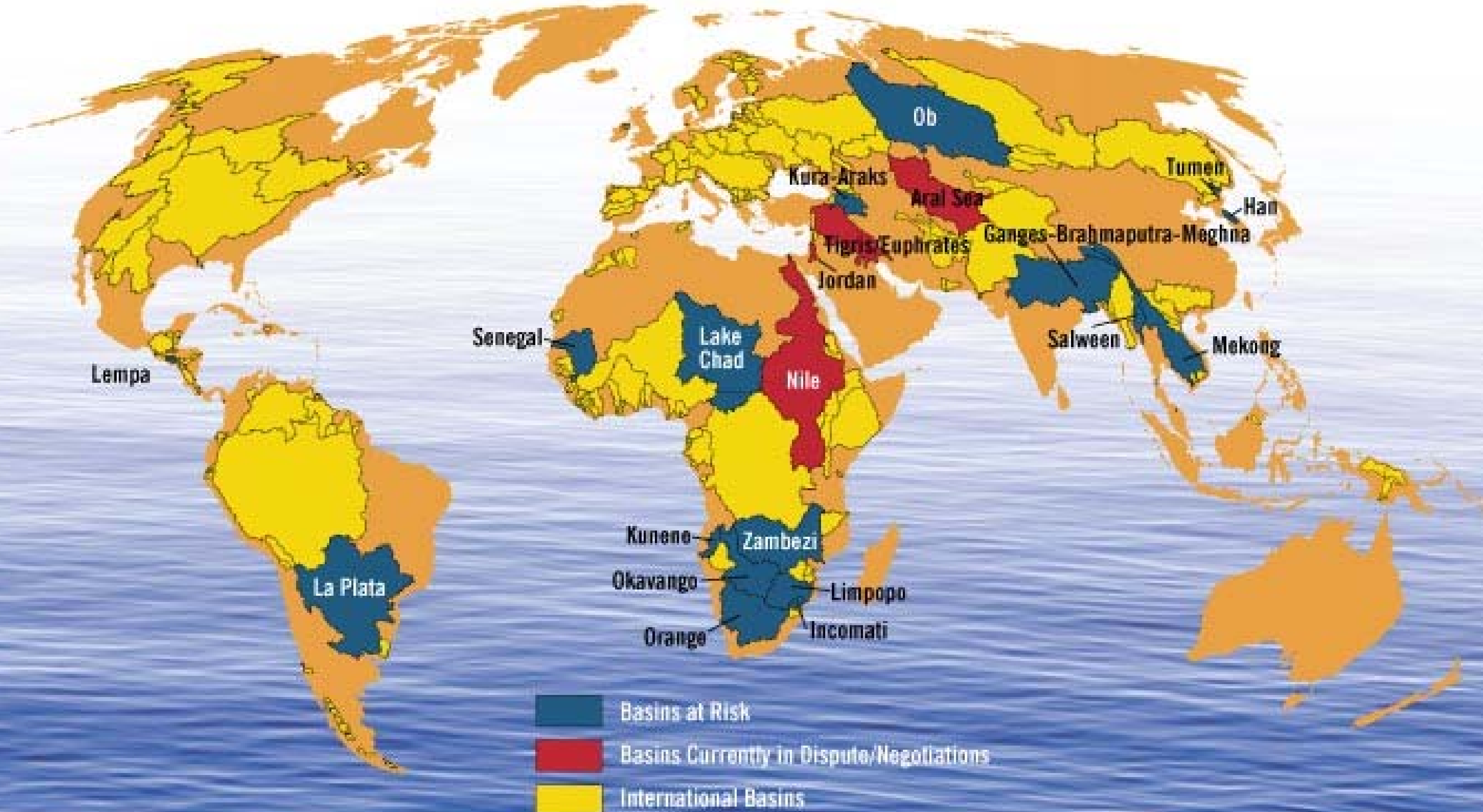


Water: More crop per drop" (E. Marris, 3-21-08)

Nature, 2008

Where we're headed: increased water tensions

"Fierce competition for fresh water may well become a source of conflict & wars in the future." **Kofi Annan)**

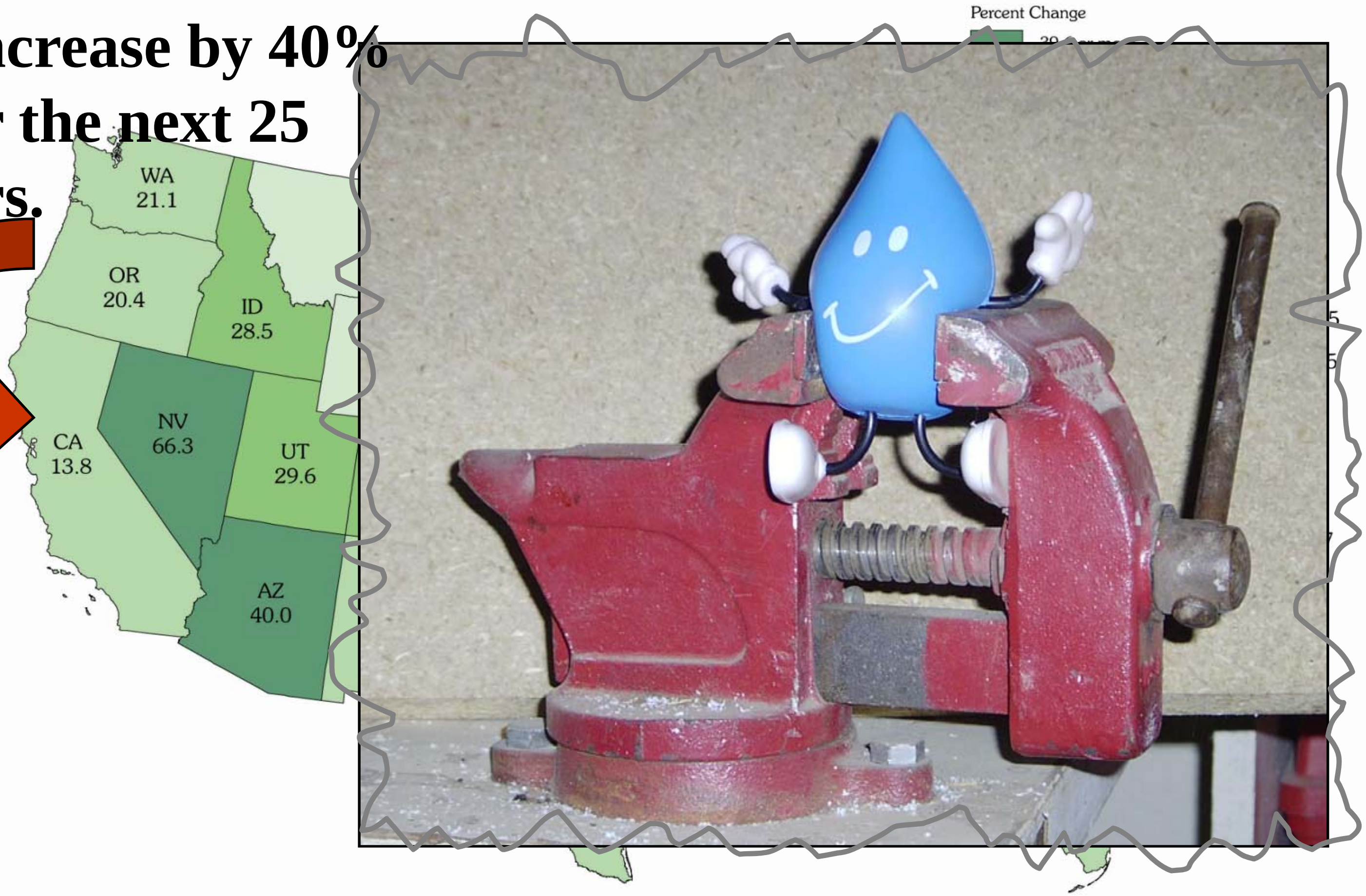


D. Grey and C.Sadoff, The World Bank, 2006

Demographic Changes: Population Has Grown Fastest in the West, Particularly in the "Public Land States"

Percent Change in Resident Population for the 48 States and the District of Columbia: 1990 to 2000

California water use to increase by 40% over the next 25 years.



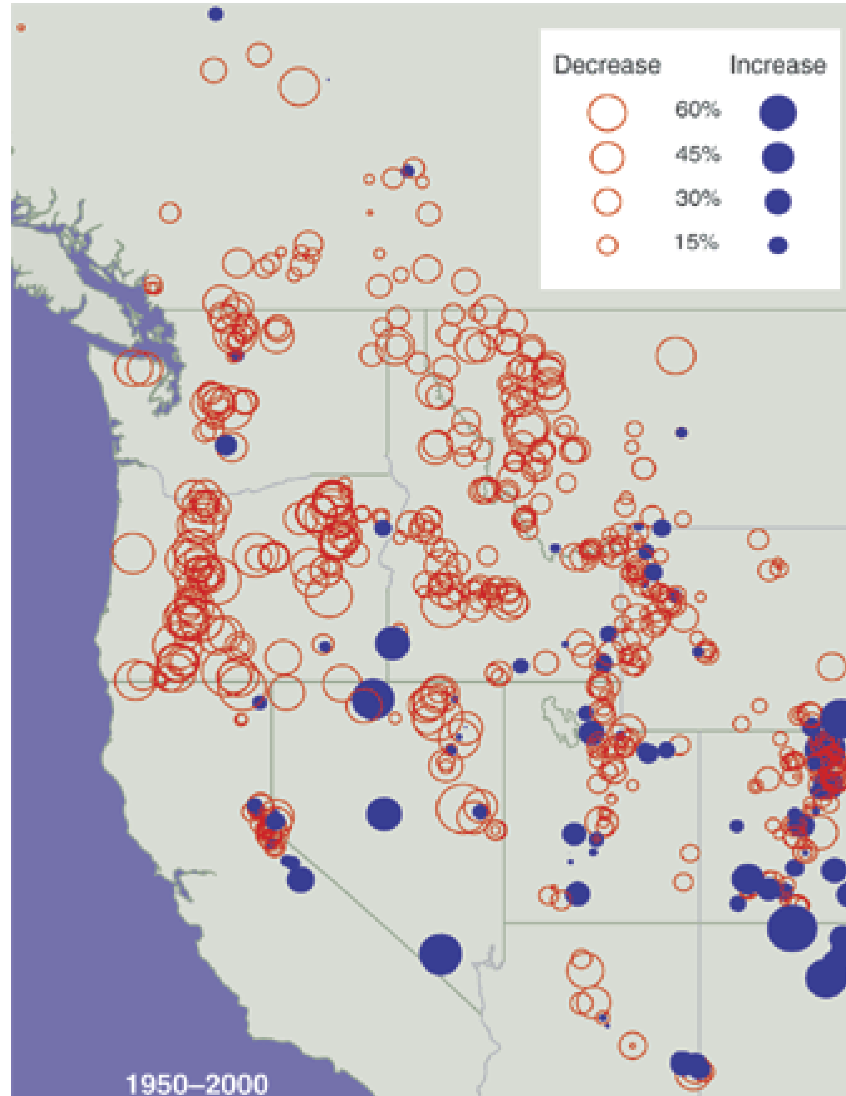
- Darker areas denote faster growth rates.

- Nevada (66%) and Arizona (40%) lead the nation.

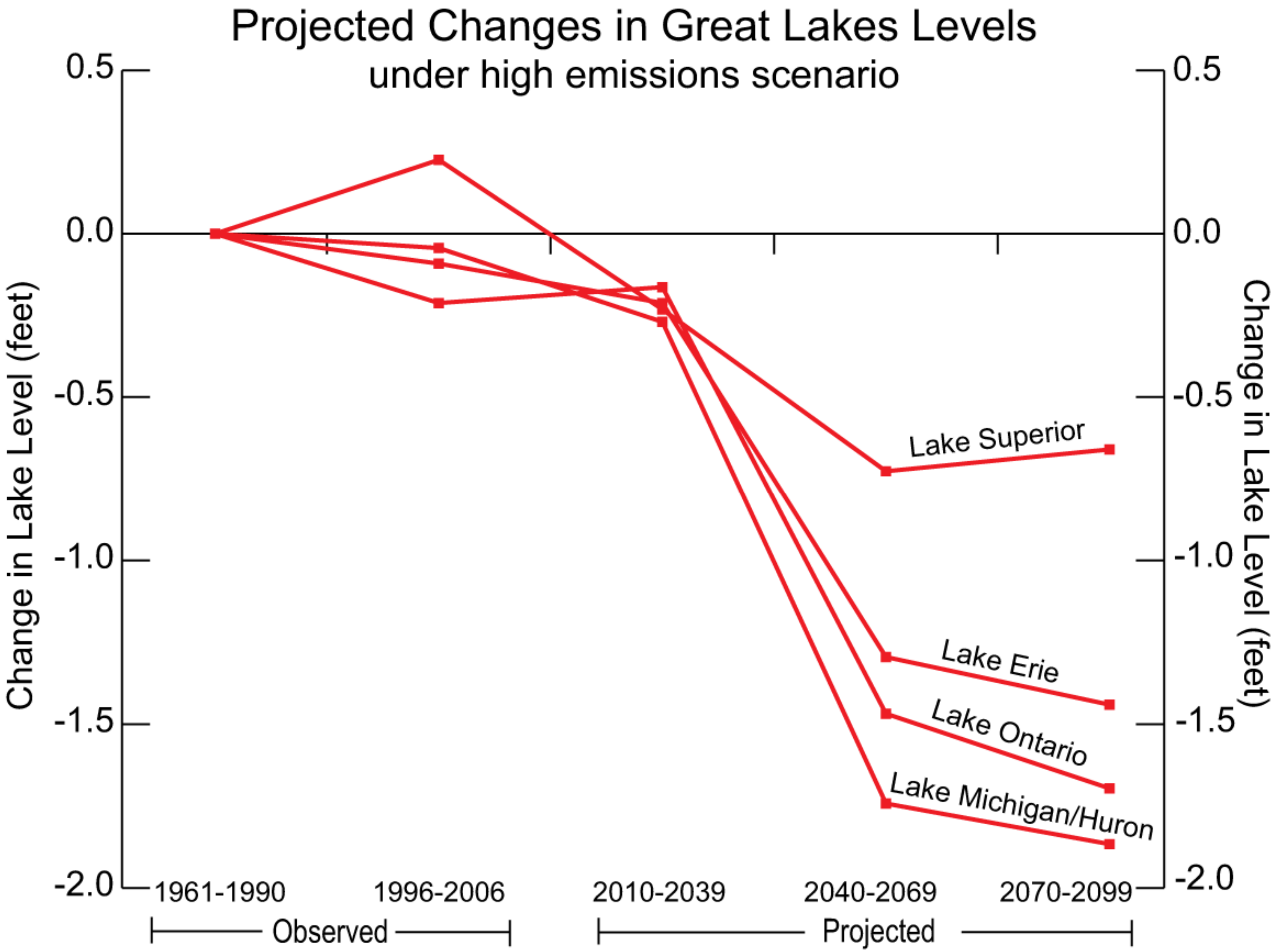
- Intermountain states average about 30%.

USCENSUSBUREAU
Helping You Make Informed Decisions

Mountain snowpack is declining

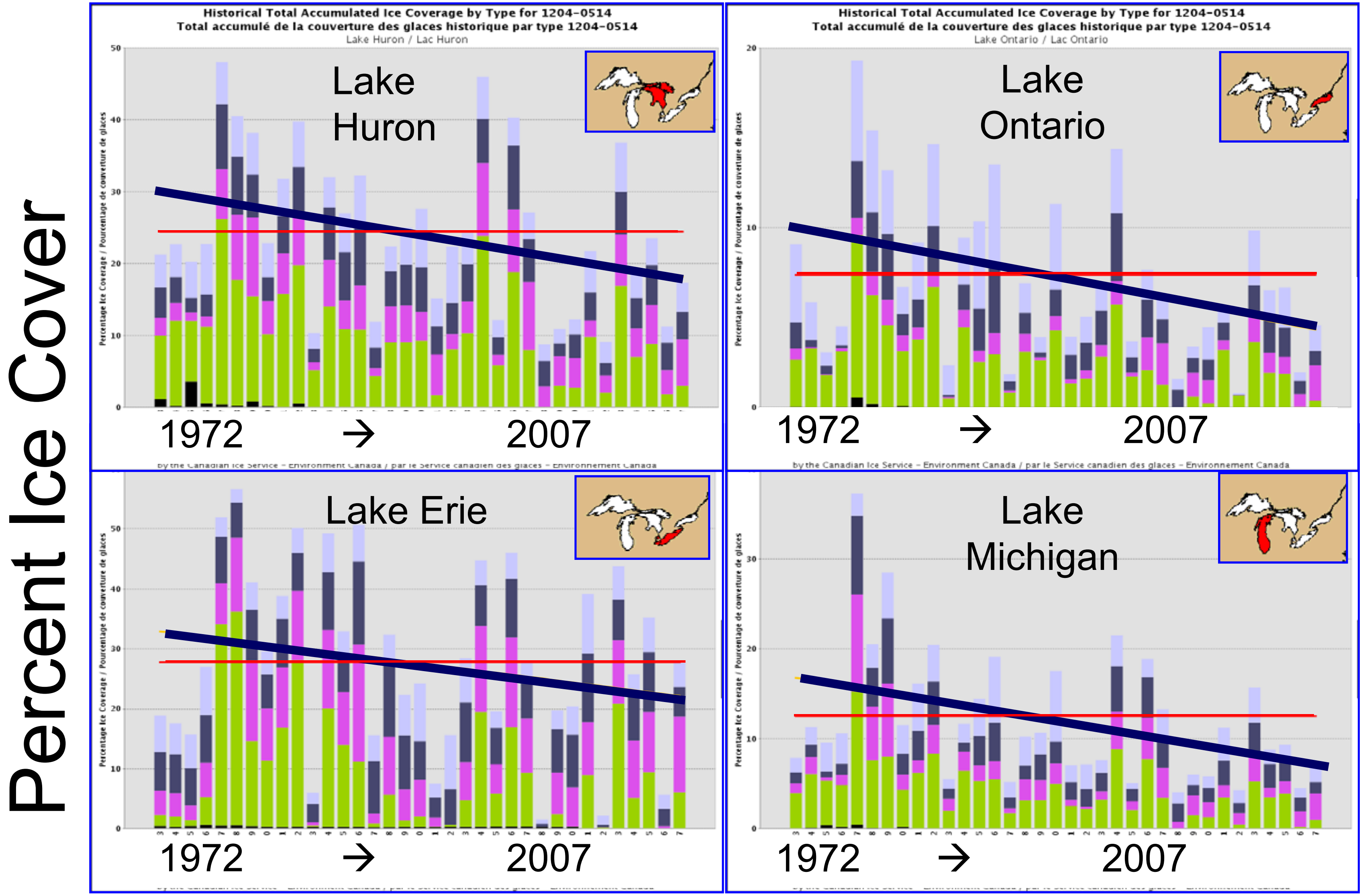


Source: P. Mote, U. of Washington



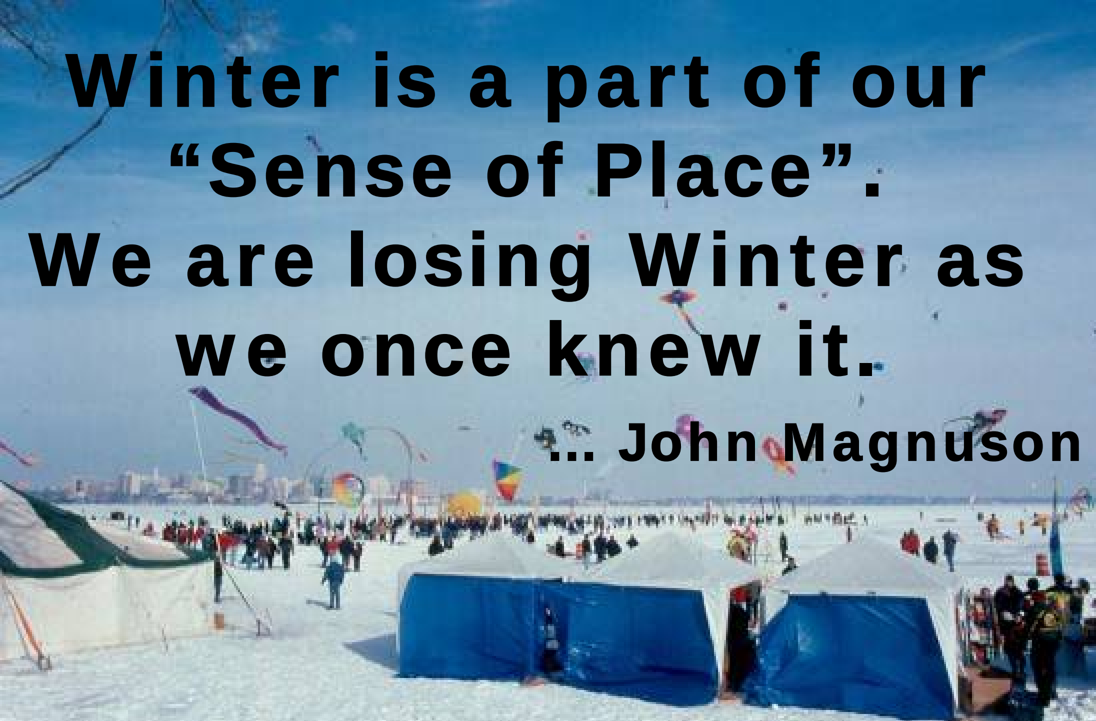
Source: *U.S. Climate Change Science Program Draft Unified Synthesis Product Report: Global Climate Change in the United States.* National Oceanic and Atmospheric Administration (NOAA), Department of Commerce. 14 July, 2008.

Consistent Patterns



Winter is a part of our "Sense of Place".
We are losing Winter as we once knew it.

... John Magnuson

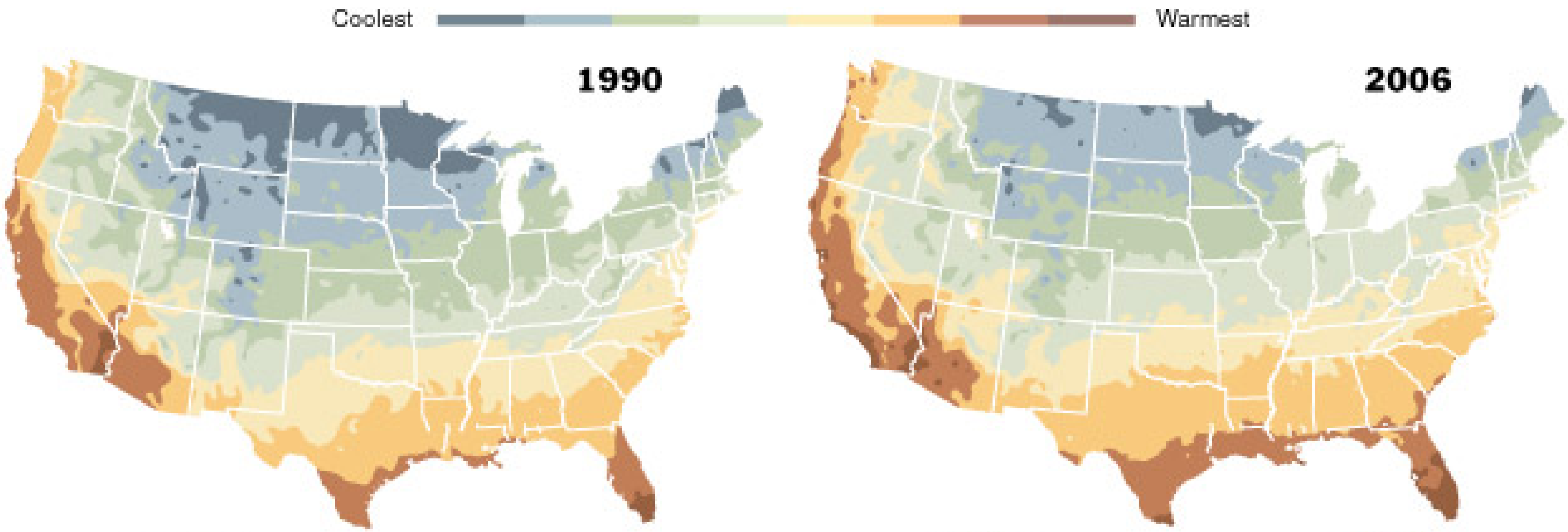


Natural Ecosystems

- Shifting zones of forests and natural areas
- Threatens National Parks and refuges
- Impacts on forestry and tourism

From: Feeling Warmth, Subtropical Plants Move North

The zones in the maps correspond to low temperatures. As warmer zones cover more of the United States, different types of plants will grow in many areas.



In the winter, **Georgia** is now hospitable to plants like firebush.

Serviceberries and dogwoods can be planted in **Nebraska**.

A warmer **New York** helps a type of fungus harmful to Canadian hemlock.

In **Seattle**, it is more difficult to grow black-eyed susans.

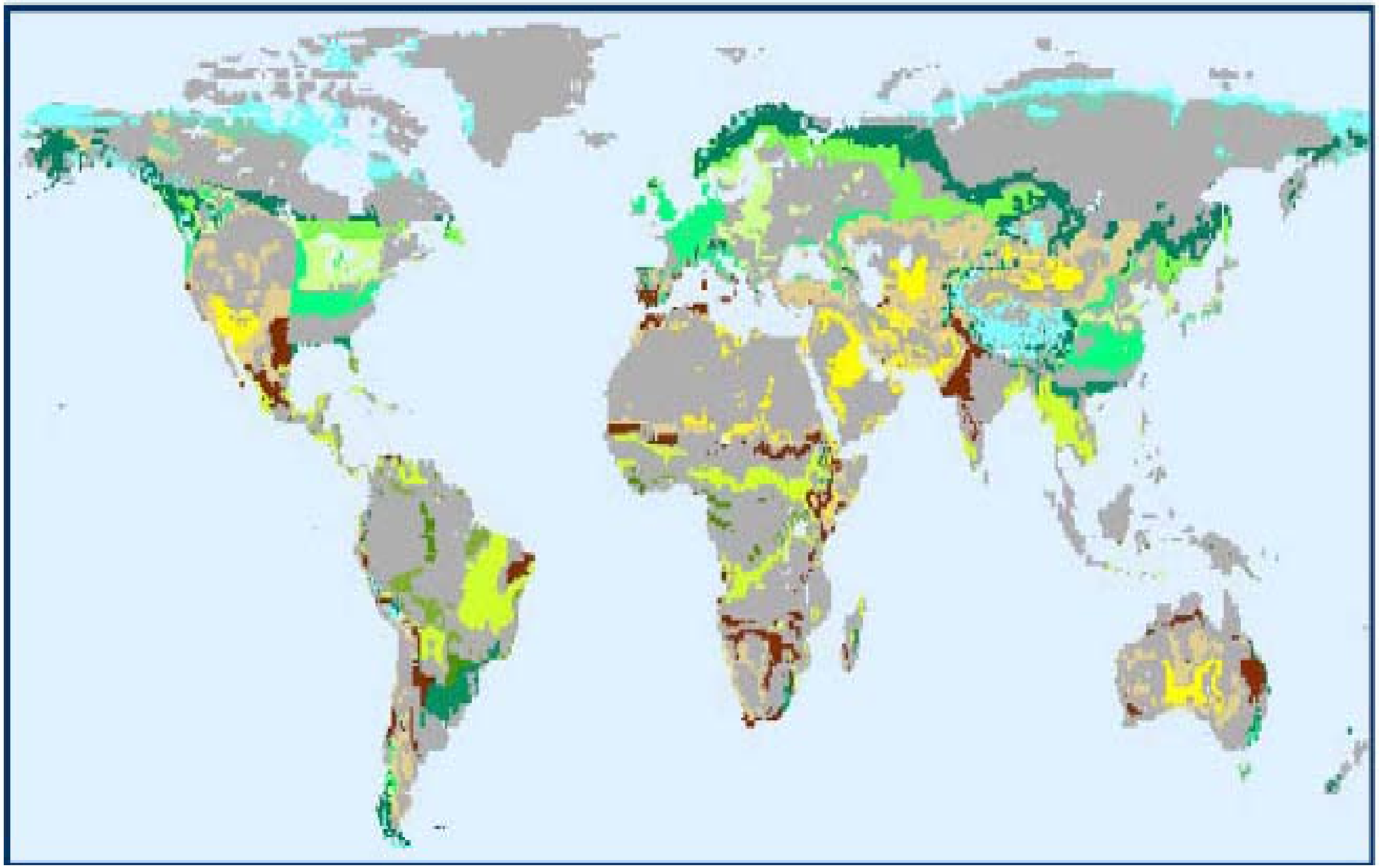
1990 zones are by the United States Department of Agriculture. 2006 zones are by the National Arbor Day Foundation.

Sources: National Arbor Day Foundation; National Wildlife Federation

The New York Times

Source: New York Times, May 3, 2007

Where we're headed: ecosystem shifts

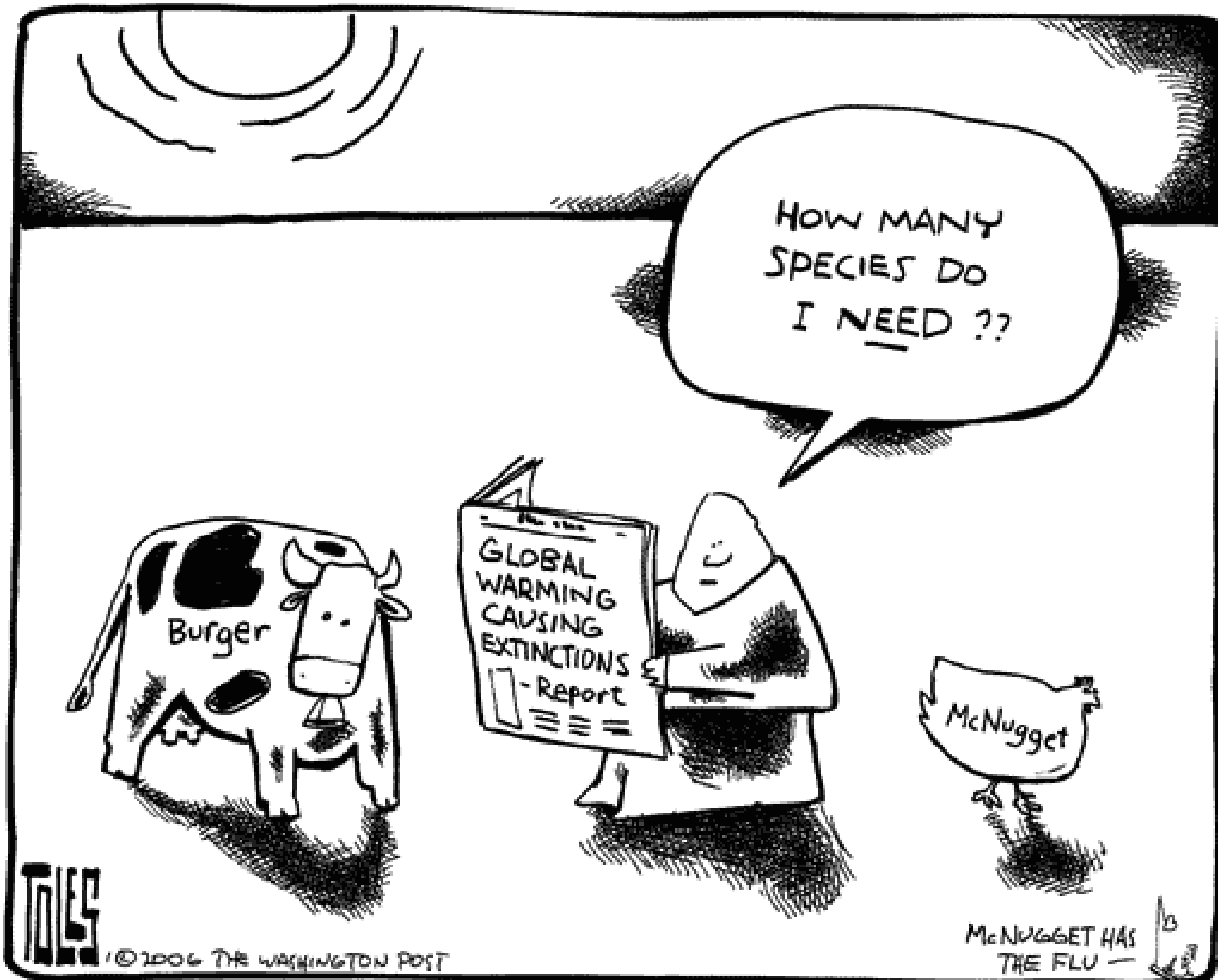


Shifts in ecosystems for a 3 degree C increase.

green=forests; brown = grasslands; yellow=deserts

Source: Leemans and Eickhout, Global Environmental Change, 2004

Say goodbye to…



HOW MANY SPECIES DO I NEED ??
GLOBAL WARMING CAUSING EXTINCTIONS - Report
Burger
McNugget
TOLES
©2006 THE WASHINGTON POST
McNUGGET HAS THE FLU —

"HE SAID WE'RE TOO FRAGILE A SPECIES TO ADAPT TO A CHANGING WORLD WITHOUT HUMAN INTERVENTION... SO I ATE HIM."

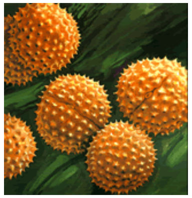
By Henry Payne, *The Detroit News*, for USA TODAY

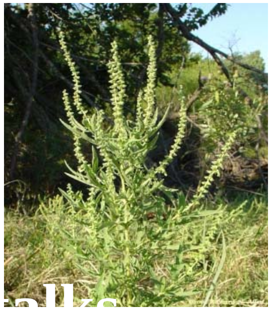
Health

- Weather Related Mortality
- Vector-borne Diseases
- Air Quality Illnesses

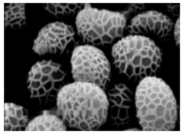
CO_2, Climate Change and Health

In our Backyards

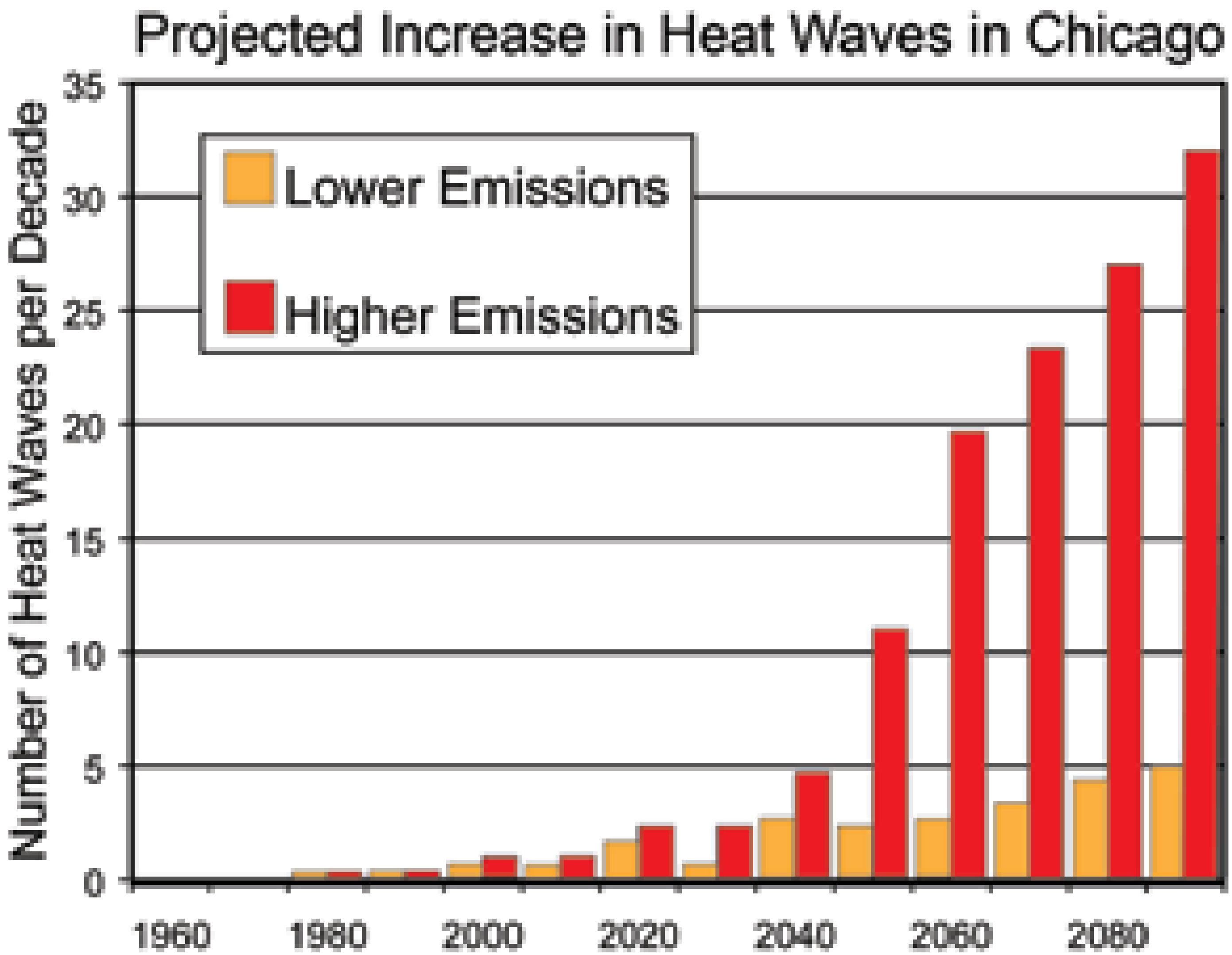




2X CO_2



P. Epstein, 2007

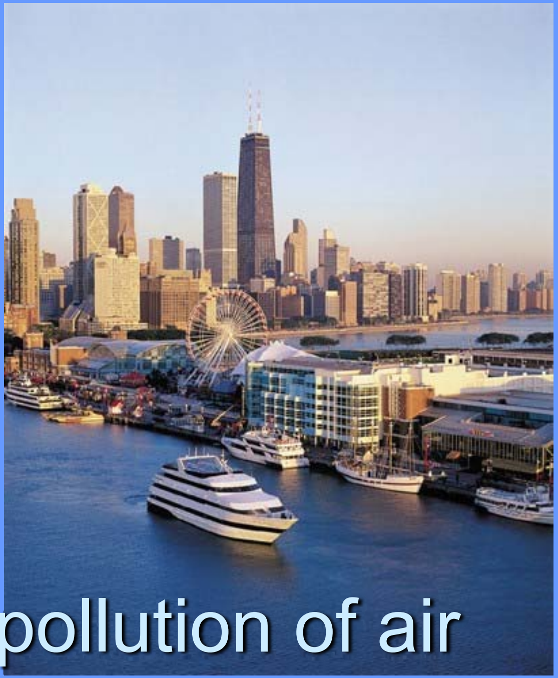


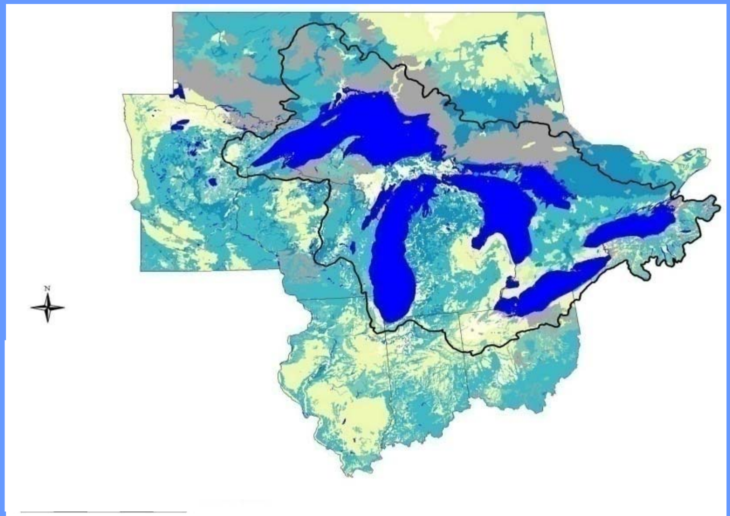
Source: *U.S. Climate Change Science Program Draft Unified Synthesis Product Report: Global Climate Change in the United States.* National Oceanic and Atmospheric Administration (NOAA), Department of Commerce. 14 July, 2008.

Communities

Climate Change Impacts Will Not Occur in a Vacuum

- Population is growing
- Increasing urbanization and sprawl
- Fragmentation of the landscape





- Industrial pollution of air and water
- Social challenges
- Geographic variability and limits

Exacerbation of Existing Problems
Property & Infrastructure

- More frequent extreme storms and floods

  - greater property damage
  - heavier burden on emergency management
  - increase clean-up and rebuilding costs
  - financial toll on businesses and homeowners

- Damage of water-related infrastructure
- Lake level drops will require more dredging and other shipping- and boating-related infrastructure adjustments

Midwest flooding, 2007

We can plan ahead…. or we can react

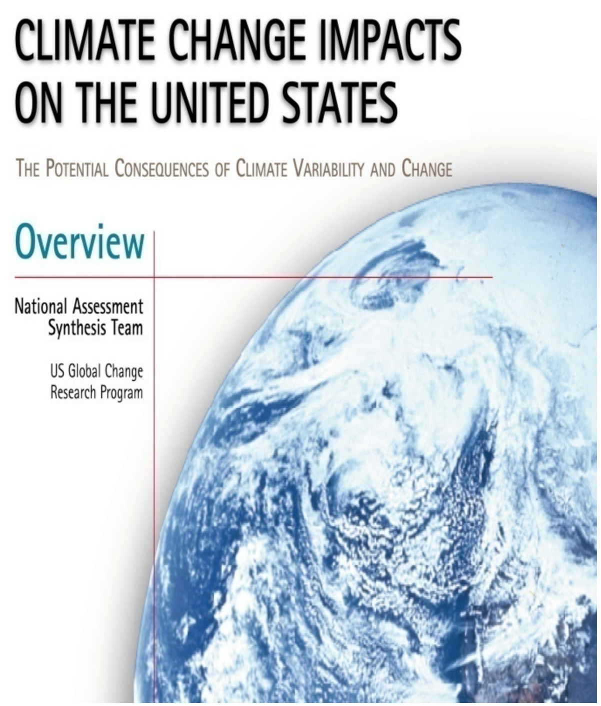
Wildlife can only react

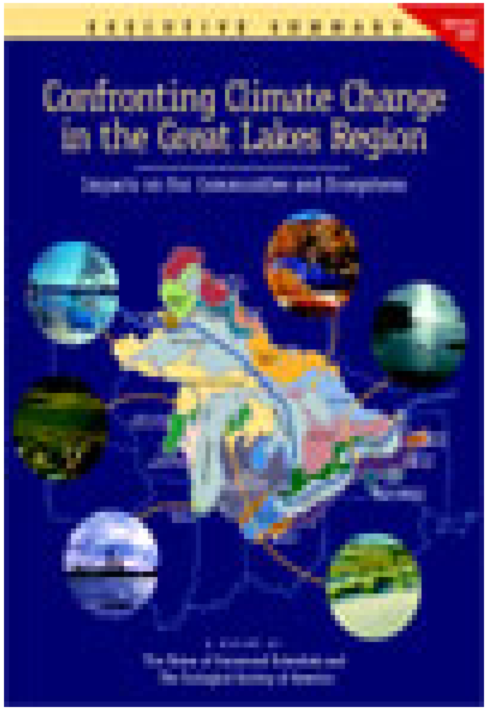
But humans can anticipate

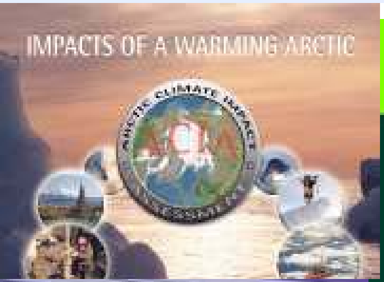
Climate Change: What do we know?

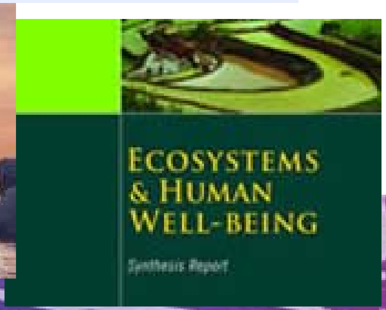
- **Past is not prologue…**
  - Infrastructure and natural resource management and planning based on the last 100 years of climate will be wrong
  - Design features of infrastructure and tolerances of species will be exceeded
- **Committed to further climate changes**
  - Adaptation <u>is</u> occurring, even if unplanned
- **Degree of warming matters**
  - Mitigation makes a difference
- **Its not just the averages that matter…**
  - Regional and local variances; seasonal changes; Extreme events
- **Need a Portfolio Approach**:
  - Adaptation <u>and</u> Mitigation—but there are interlinkages across the two!
- **Adaptive Management is needed**
  - In all sectors and regions
- **Investment is not commensurate with the urgency of the problem…**
  - Need integrative regional assessments involving stakeholders
  - Need prioritization of policy-relevant research needs across fields, not laundry lists

There have been lots of Assessments….of sorts…





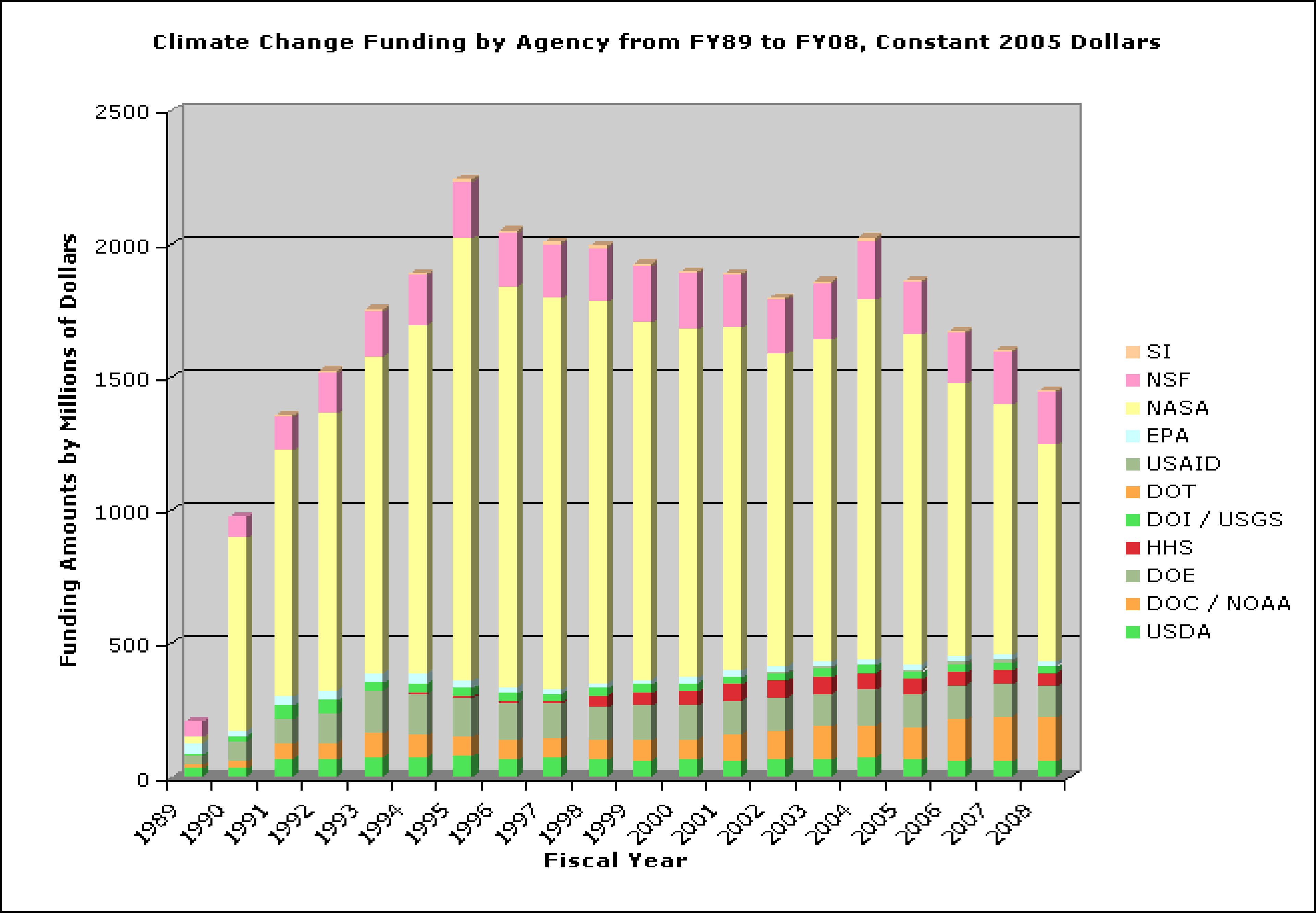




NRC Report on CCSP* (9/12/07)

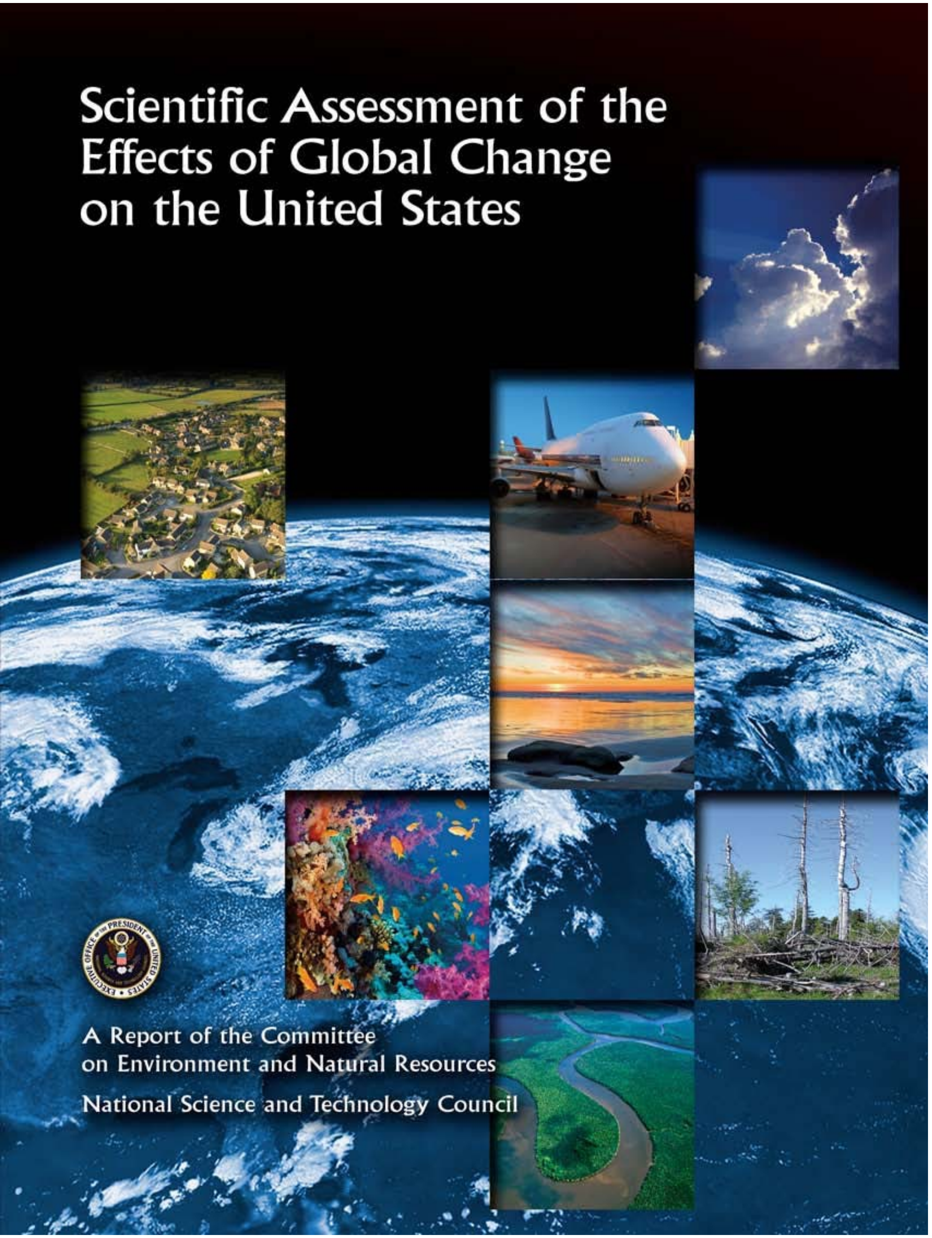
- Understanding and predicting <u>physical</u> climate change is progressing well
- Declining observing capability
- Inadequate human dimensions funding:
  - $30 million; lack of collaboration
- Inadequate progress
  - in assessing impacts on human well being and vulnerabilities
  - in providing knowledge to support decision making and risk analyses
  - in communicating results and engaging stakeholders in a two-way dialogue

*Evaluating Progress of the US CCSP Program: Methods & Preliminary Results



http://www.usgcrp.gov/usgcrp/budgets/funding1989-2008byagency.htm

Released, May 30, 2008



And, up for review July 14, 2008 *:*
U.S. Climate Change Science Program Draft Unified Synthesis Product Report: Global Climate Change in the United States. (NOAA).

http://www.climatescience.gov/Library/sap/usp/public-review-draft/


coping with
climate change
National Summit
May 8-10, 2007

Adaptation options include:
planning/management, technology, institutions, monitoring, & R&D

- Infrastructure to withstand new “extremes”
- Linking of reservoirs to enhance supply
- Seed banks, mass propagation techniques
- Emergency response plans
- Early warning alert systems / surveillance
- Incentives / Disincentives / insurance
- Prioritize lands to preserve
- Design of migration corridors

Climate Change: Adaptation Needs

Four essential categories of analysis needed to develop adaptation options

- Evaluate the impacts of Multiple Stresses on systems
- Apply the appropriate Scale—Regional/watershed
- Prepare for Extreme Events and their Consequences
- Explore the intersection of mitigation and adaptation

Rosina M. Bierbaum

Climate Change: Adaptation Needs

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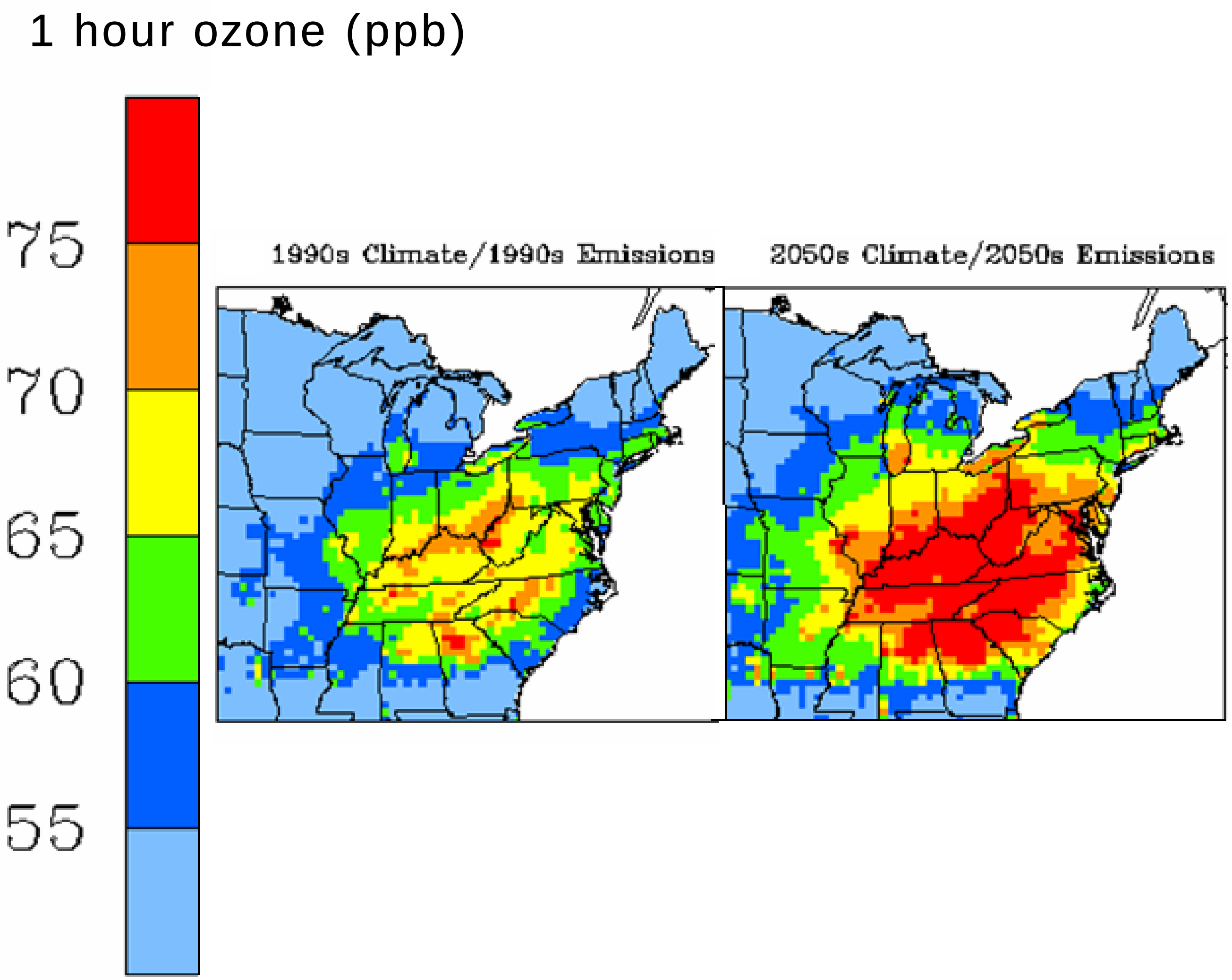
Rosina M. Bierbaum

Figure 5.4 Aerial view of the U.S. Forest Service Rocky Mountain Research Station's Fraser Experimental Forest near Winter Park, Colorado, May 2007 and a mountain pine beetle (inset). The green strips are areas of forest that had been harvested decades earlier, and so have younger faster growing trees. The red and brown areas show dead and dying trees caused by bark beetle infestation. A more recent photo would show less contrast because, due to drought and beetle epidemic, mortality rates of young trees have also risen. Photo courtesy USFS, Rocky Mountain Research Station.

Linkage Between Climate and Air Quality



Impact on
Ozone Formation
of
Changes in Climate
vs.
Changes in
Emissions

New York Climate & Health Project

Climate Change: Adaptation Needs

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Summary of ***Projected*** Trends

- **Temperature**
  - Winter 5-12 °F (3-7 °C)
  - Summer 5-20 °F (3-11 °C)
  - Extreme heat more common
- **Precipitation**
  - Winter, spring increasing
  - Summer, fall decreasing – drier soils, more droughts
- **More extreme events** – storms, floods
- **Ice cover decline will continue**
- **Lake levels likely to continue to decline**

Impacts on the Midwest

- **Public health and quality of life,** especially in cities, will be negatively affected by increasing heat waves, reduced air quality, and insect- and water-borne disease.

- Under higher emissions scenarios, **significant reductions in Great Lakes water levels** will impact shipping, infrastructure, beaches and ecosystems.

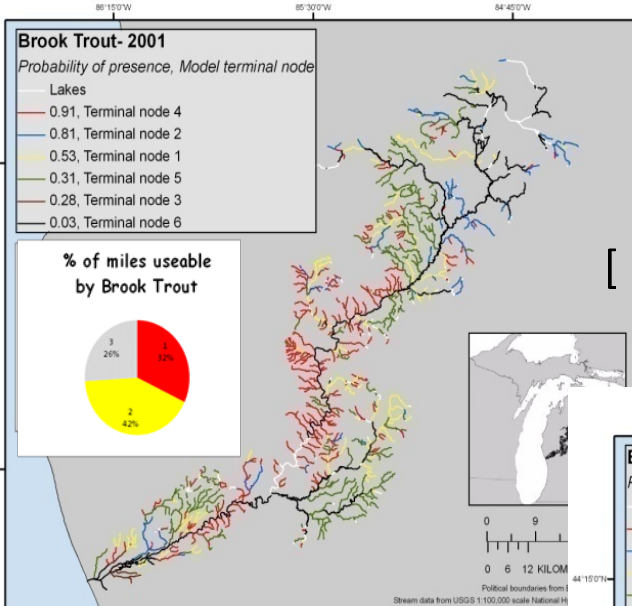
- Increasing precipitation in winter and spring, more heavy downpours, and greater evaporation in summer will mean **more periods of both floods and water deficits.**

- While a longer growing season provides the potential for increased crop yields, **increases in heat waves, floods, droughts, insects, and weeds** will present increasing challenges to crops, livestock, and forests.

- **Native species will face increasing threats** from rapidly changing climate conditions, pests, diseases, and invasive species moving in from warmer regions.

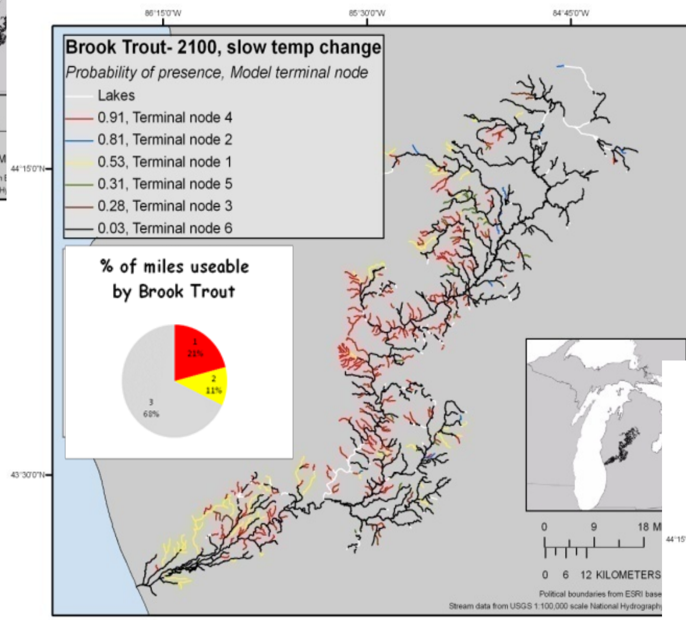
Source: *U.S. Climate Change Science Program Draft Unified Synthesis Product Report: Global Climate Change in the United States.* National Oceanic and Atmospheric Administration (NOAA), Department of Commerce. 14 July, 2008.

Current: 2001]

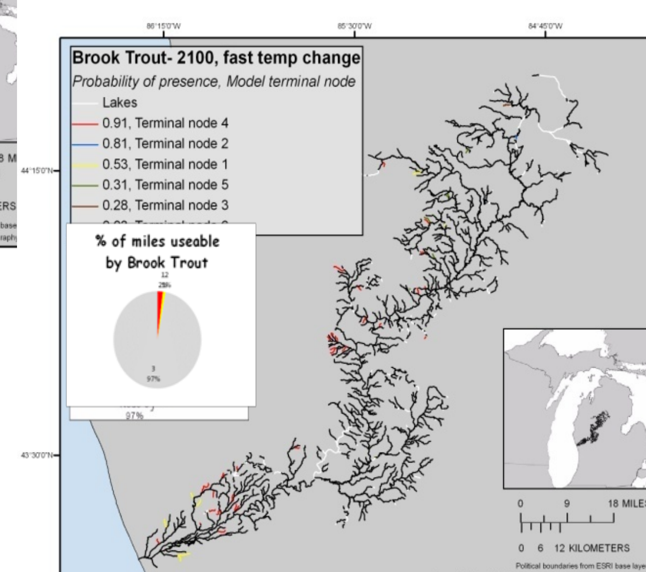


Modeling land cover change impacts on Brook Trout habitat:

[2100 1 ^{o}C increase in temp]



[2100 3 ^{o}C increase in temp]



*<u>Business As Usual Scenario</u>

- Regional average sprawl rate
- Declining agriculture
- Forest regeneration

P. Steen, in press, 2008.

Climate Change: Adaptation Needs

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Rosina M. Bierbaum

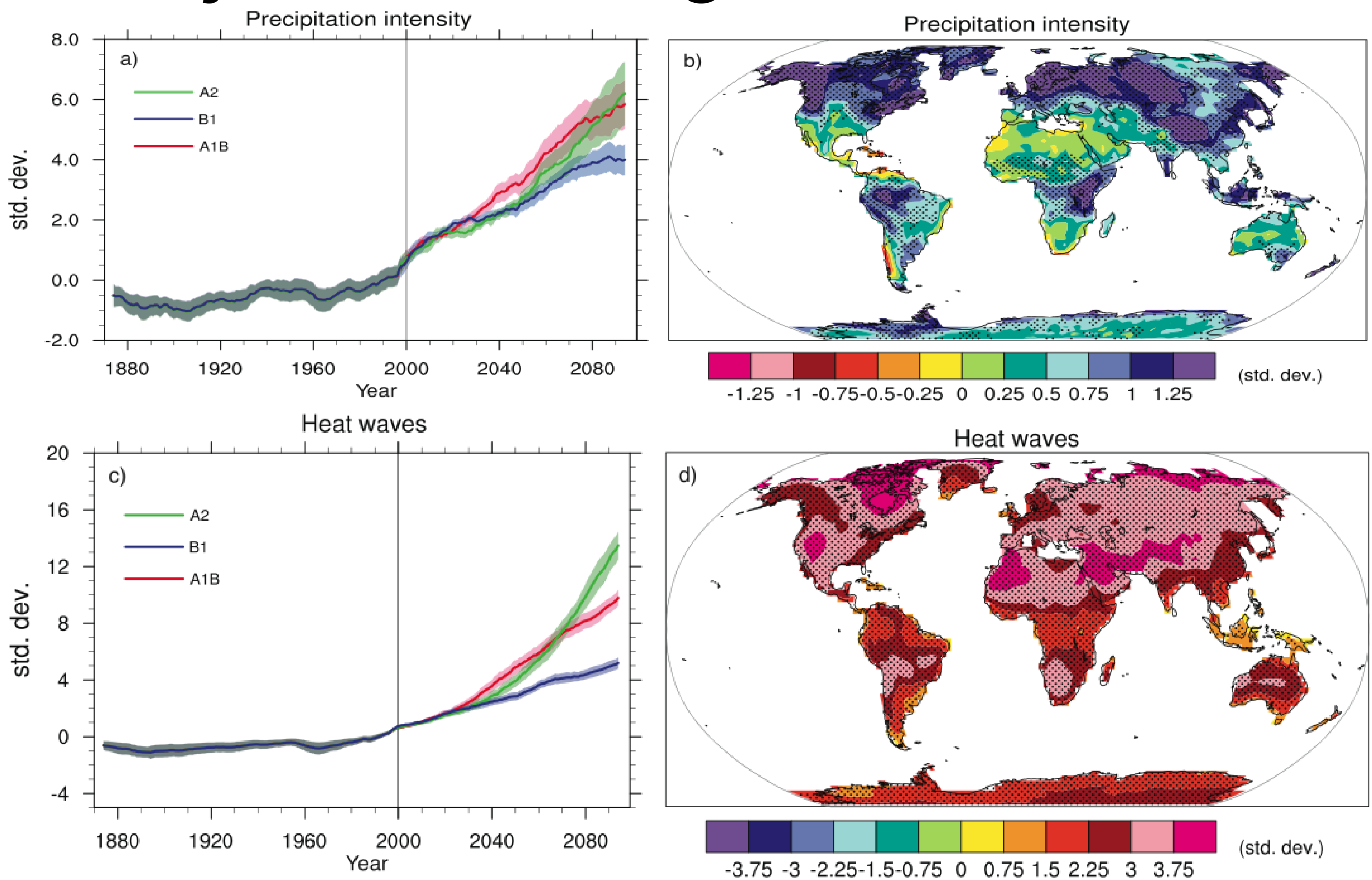
Photo by G. Lang.

Low lake levels at Old Mission Point lighthouse in Lake Michigan in 2001.

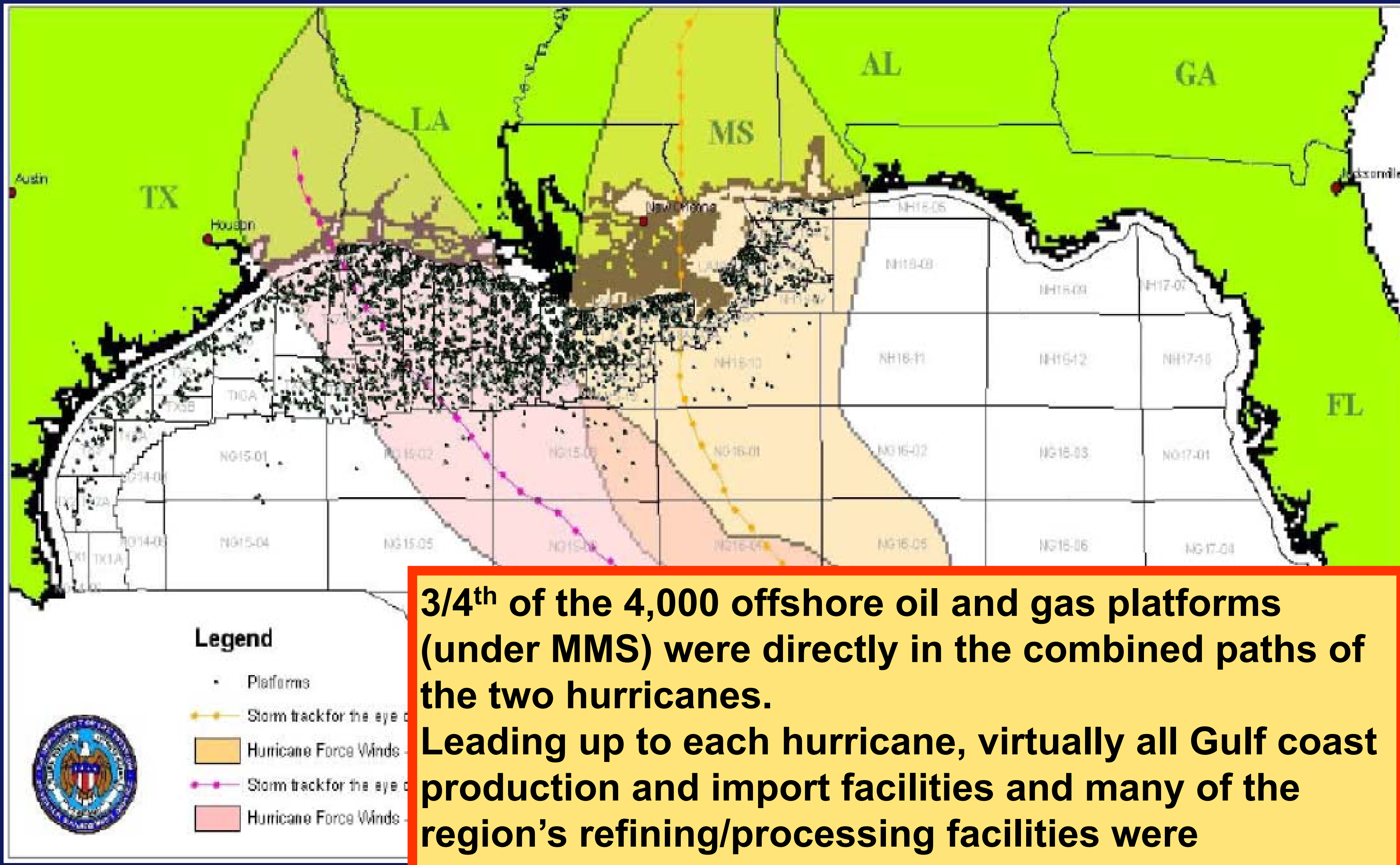
High lake levels on Lake Michigan in 1986 caused severe erosion.

NOAA 2007

Projected changes in extremes

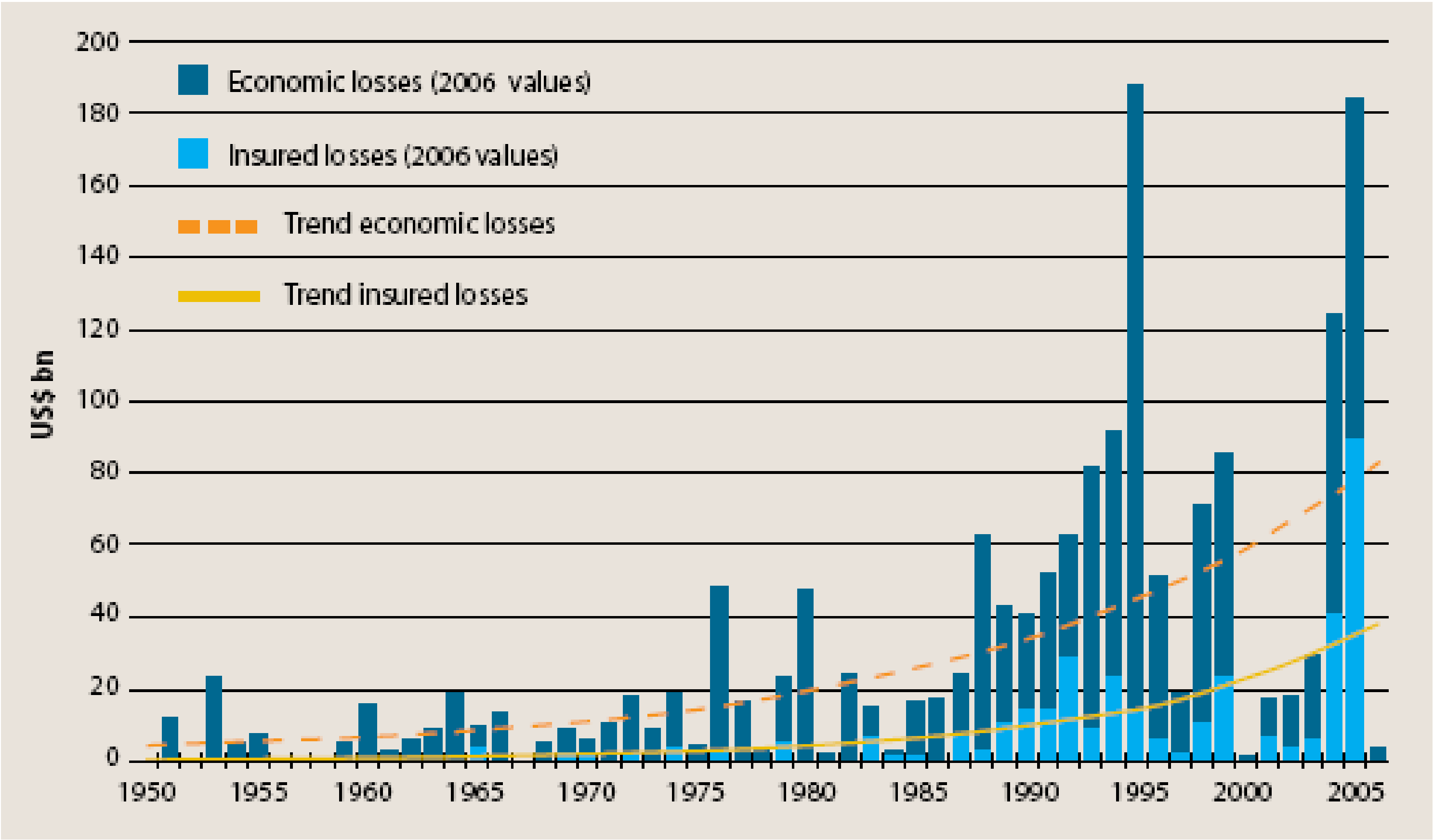


Example:
Drilling Platforms vis-à-vis Hurricanes Katrina and Rita



3/4th of the 4,000 offshore oil and gas platforms (under MMS) were directly in the combined paths of the two hurricanes.
Leading up to each hurricane, virtually all Gulf coast production and import facilities and many of the region's refining/processing facilities were evacuated or operations were otherwise suspended.

Global costs of extreme weather events from 1950–2006 (adjusted for inflation)

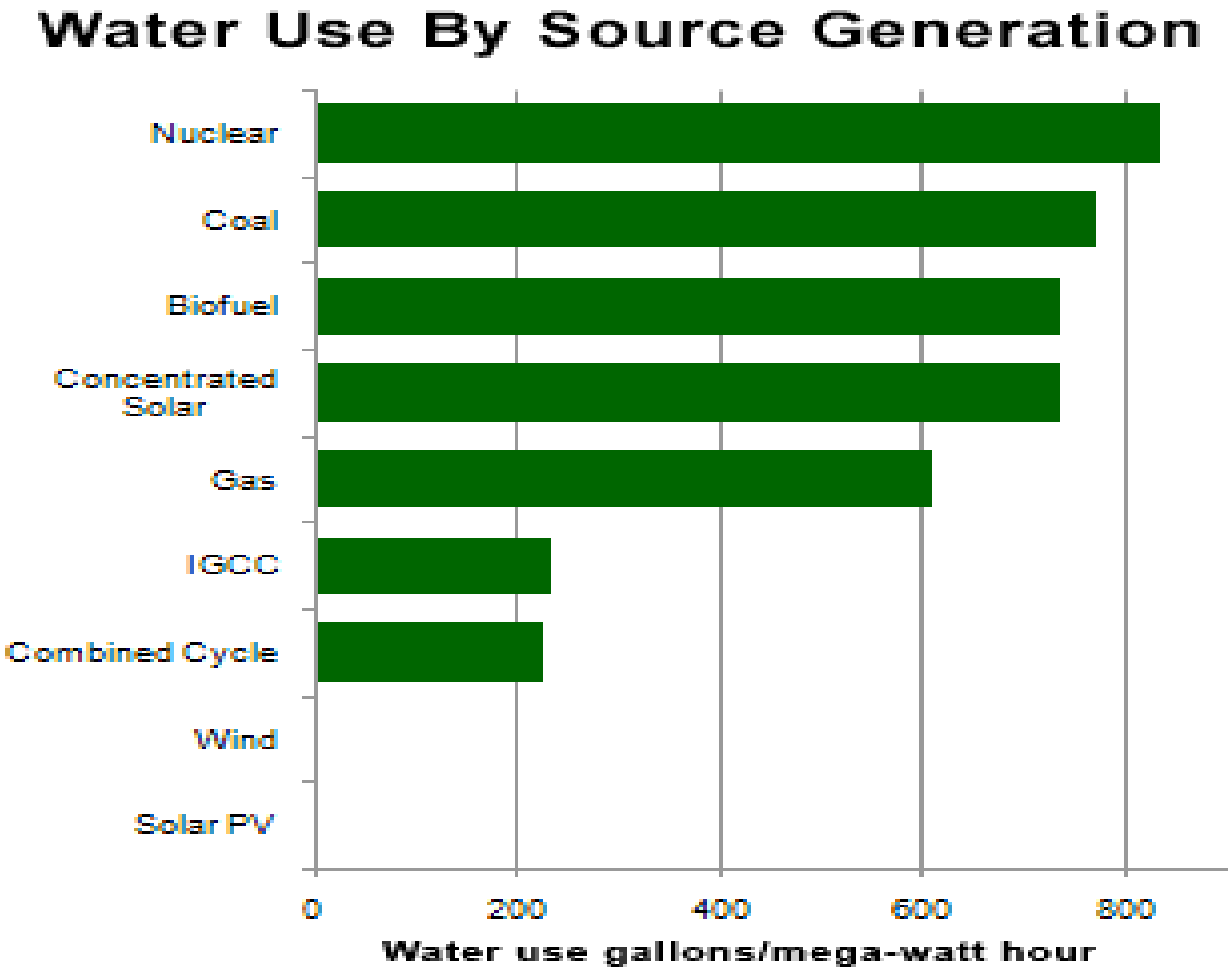


UNEP, 2008

Climate Change: Adaptation Needs

- **Evaluate the impacts of Multiple Stresses on systems**
- **Apply the appropriate Scale—Regional/watershed**
- **Prepare for Extreme Events and their Consequences**
- **Explore the intersection of mitigation and adaptation**

There are intersections between mitigation and adaptation…



and water is a linchpin….

Electric Power Research Institute, 2007

Water Requirements for Energy Supply

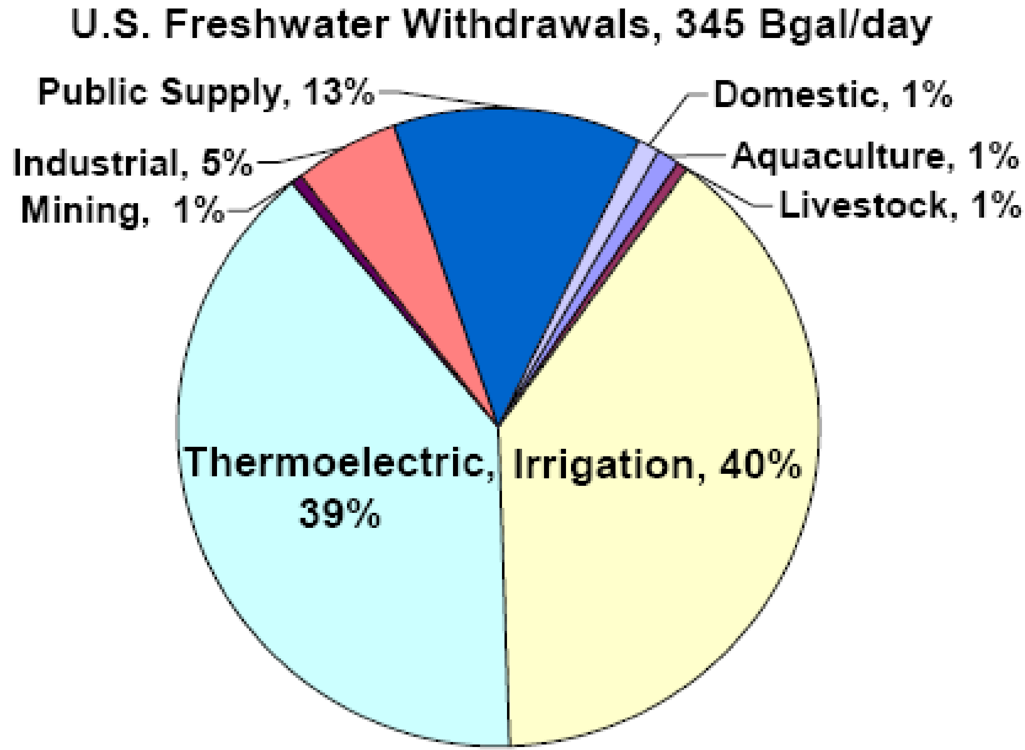
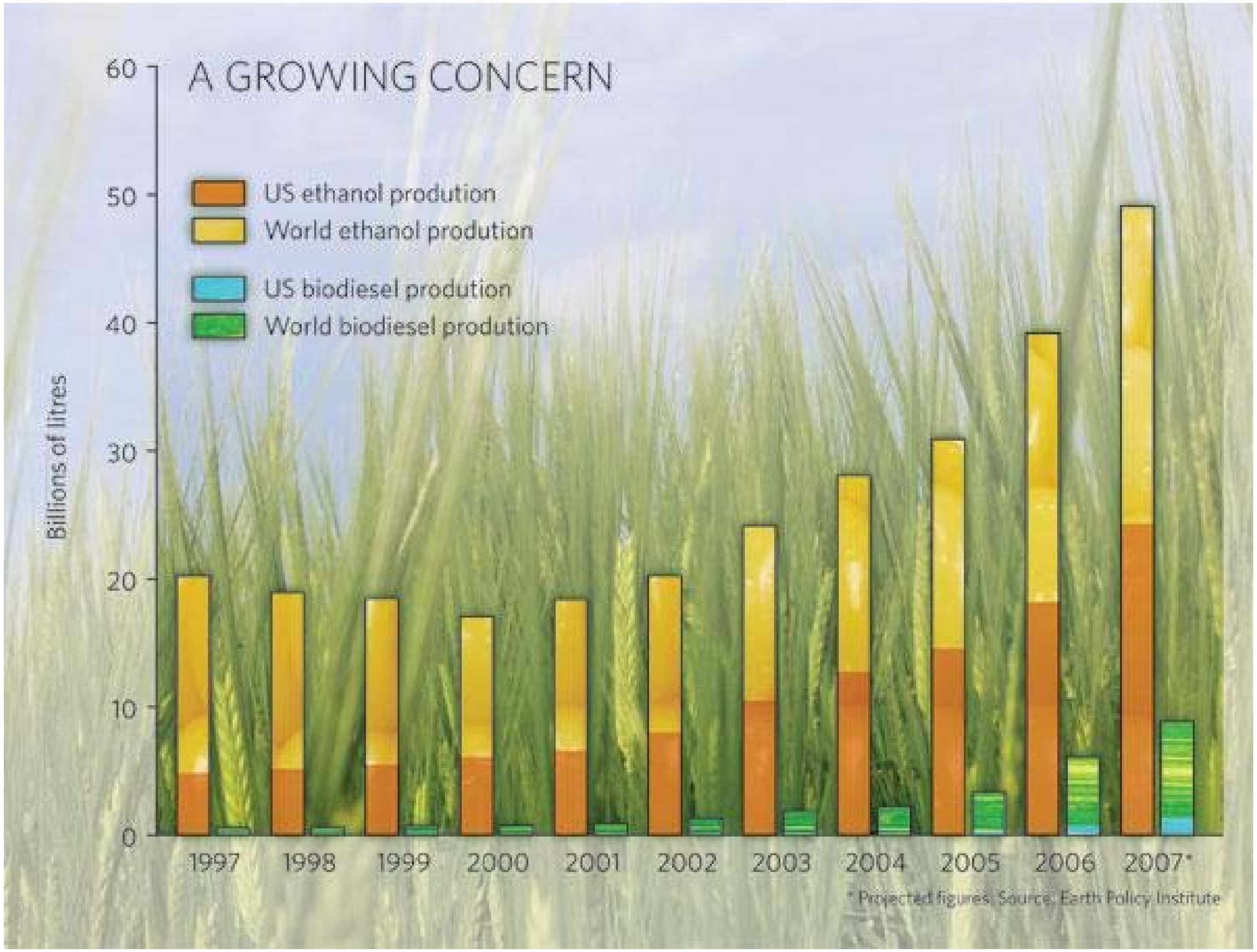


Figure II-1. Estimated Freshwater Withdrawals by Sector, 2000 (Hutson et al., 2004)

Ethanol and Biodiesel Production

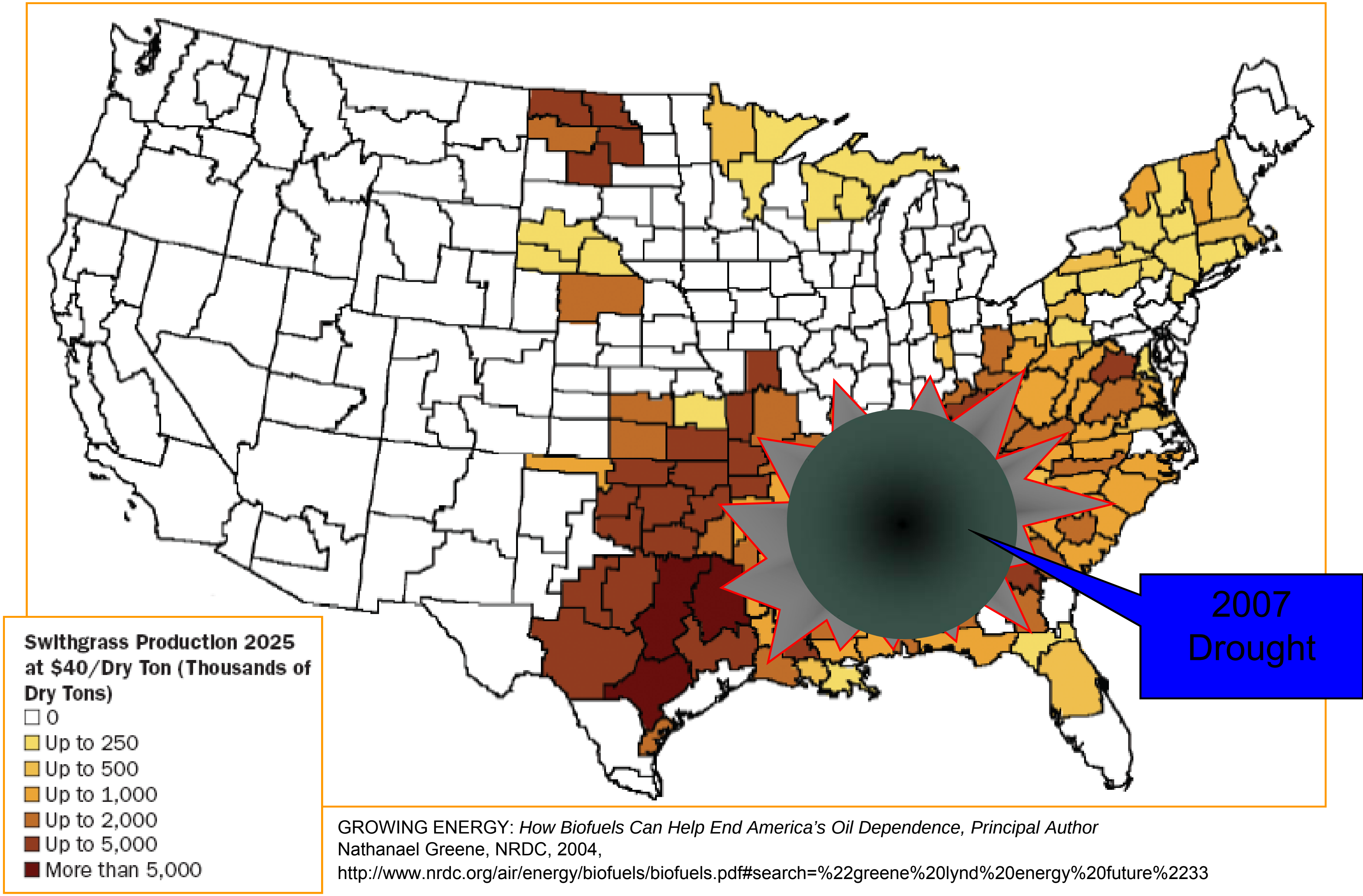


“Energy: Not your father's biofuels" (J. Tollefson, 2-21-08)

Nature, 2008

Switchgrass Production –

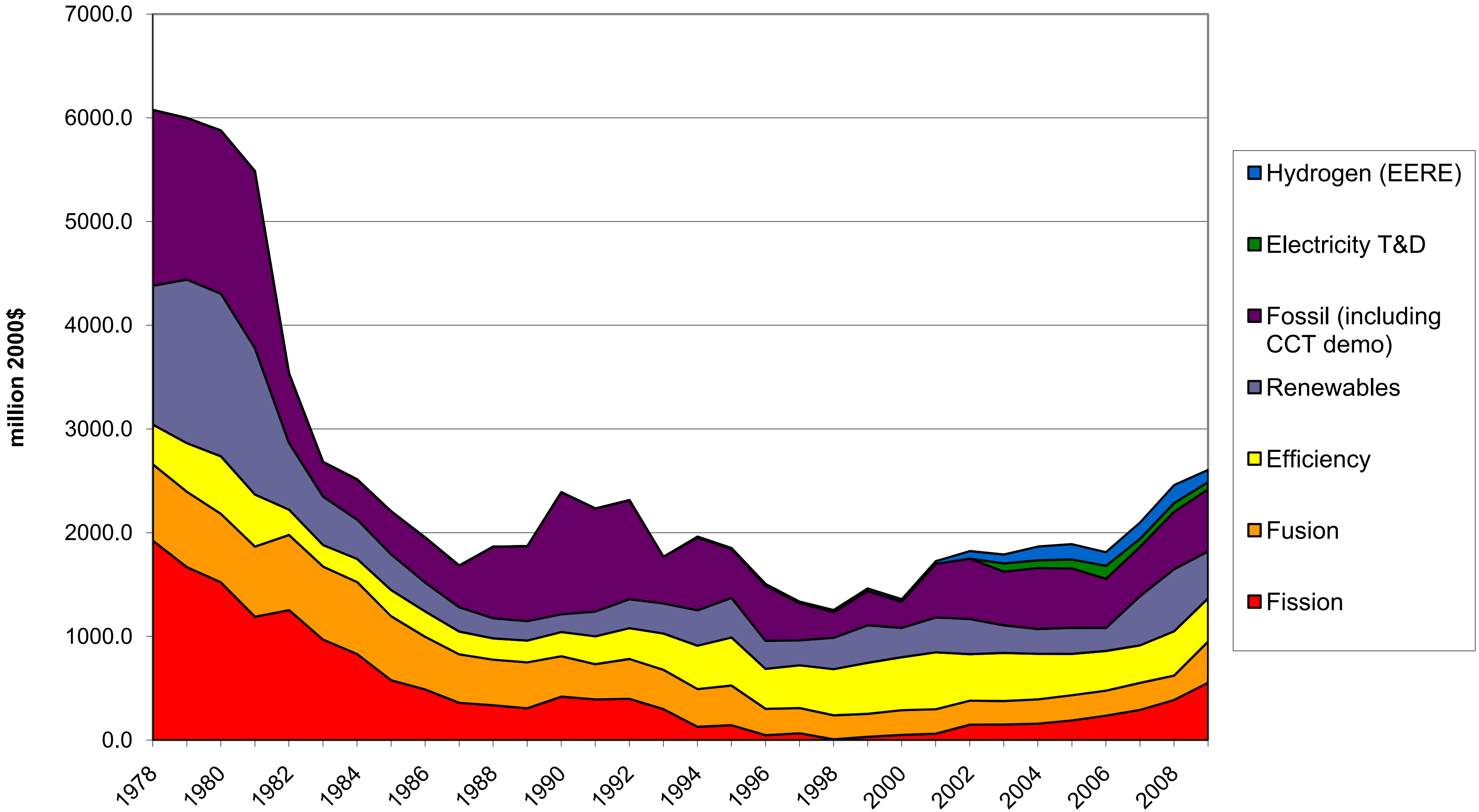
the “potential” for cellulosic biomass



GROWING ENERGY: *How Biofuels Can Help End America’s Oil Dependence, Principal Author* Nathanael Greene, NRDC, 2004, http://www.nrdc.org/air/energy/biofuels/biofuels.pdf#search=%22greene%20lynd%20energy%20future%2233

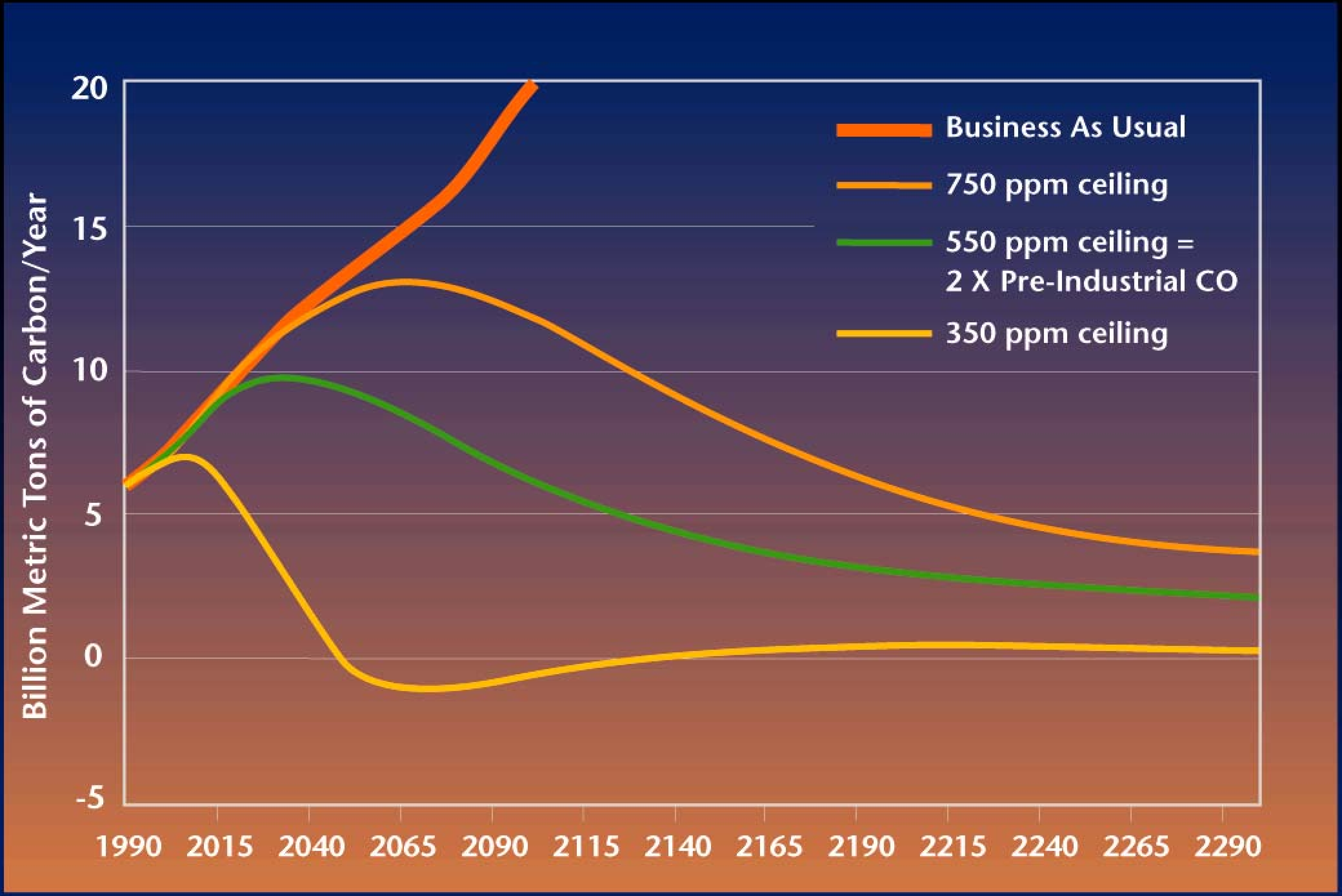
http://www.nytimes.com/imagepages/2007/07/04/us/20070705_DROUGHT_GRAPHIC.html

U.S. DOE Energy RD&D
1978-FY2009 Administration Request



Kelly Sims-Gallagher, Havard, 2008

Atmospheric Stabilization Emissions Paths



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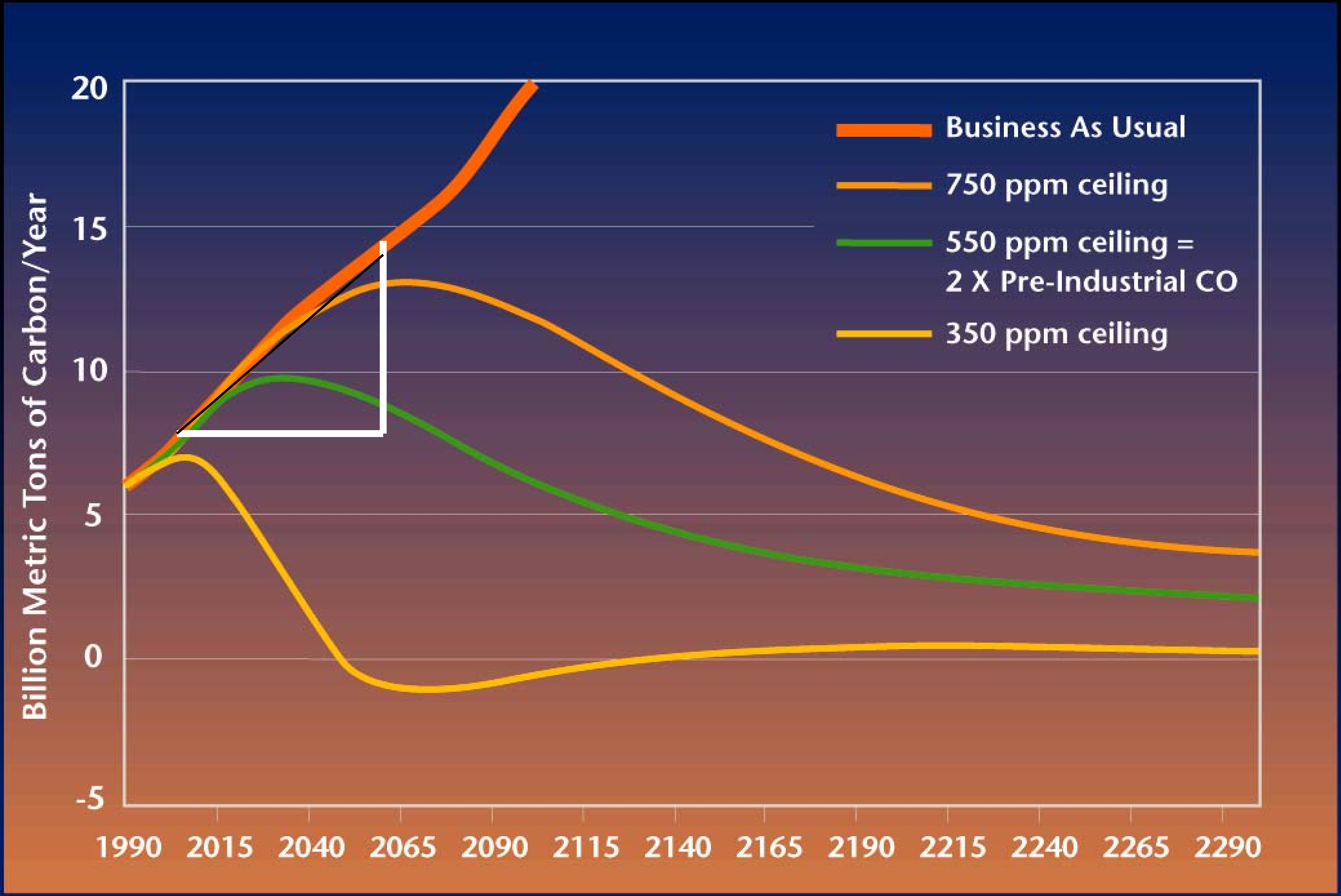


Fifteen example wedges

CO_2 Capture & Storage (CCS)

CO_2 capture:

1. Introduce CCS at 800 GW coal or 1600 GW natural gas plants (1100 GW coal today)
2. Introduce CCS at plants producing 250 MtH_2/yr from coal or 500 MtH_2/yr from natural gas (40 MtH_2/yr today)
3. Introduce CCS at synfuels plants producing 30 mbd from coal (200x Sasol)

H_2 safety, infrastructure

Geologic storage: Create 3500 Sleipners

Durable storage

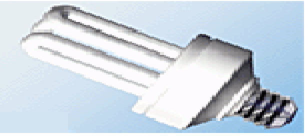
Wind and Solar

4. Add 2 million 1-MW-peak windmills (50 times current level) on 30 Mha, displacing coal electricity
5. Add 2000 GW-peak PV plants (700 times current level) on 2 Mha, displacing coal electricity

6. Add 4 million windmills or 4000 GW-peak PV plants generating 200 MtH_2/yr, displacing gasoline hybrid cars

Energy storage, H_2 safety, infrastructure
PV production cost

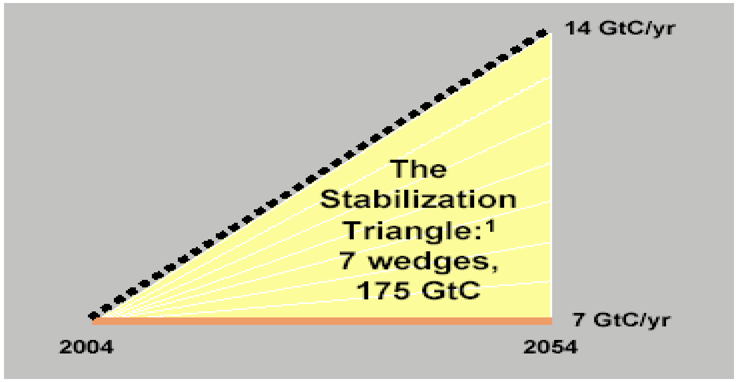
Energy Efficiency & Conservation



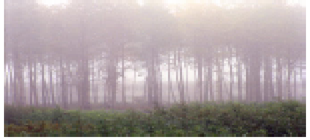
Increase economy-wide emissions/GDP reduction by additional 0.15%/yr (e.g. increase US goal of 1.96%/yr to 2.11%/yr):

8. Increase fuel economy for 2 billion cars from 30 to 60 mpg
9. Decrease car travel for 2 billion 30-mpg cars from 10,000 to 5,000 miles/yr
10. Cut carbon emissions in buildings/appliances by 1/4 over 2054 projection
11. Produce twice today's coal output at 60% efficiency instead of 40% (compare with 32% today)

Weak incentives, urban design, lifestyle changes



Forests & Soils



14. Decrease tropical deforestation to zero instead of 0.5 GtC/yr, and establish 300 Mha of new tree plantations (twice current level)
15. Implement conservation tillage on all cropland (10 times current level)

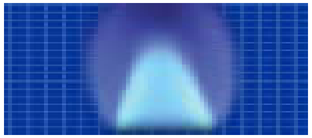
Competing land use, verification, reversibility

Nuclear Fission

13. Add 700 GW nuclear plants (compare with 350 GW today) replacing coal

Nuclear proliferation, terrorism, waste

Fuel Switching



12. Replace 1400 GW coal plants with natural gas plants (compare with 350 GW natural gas today)

Competing demands for natural gas

Biomass Fuel

7. Add 50 times current US and Brazil ethanol production on 250 Mha (1/6 world cropland)

Biodiversity, competing land use

Beyond 2054

More wedges will be needed to maintain the trajectory established by the stabilization triangle, and scaling up the above technologies are unlikely to be enough to satisfy growing energy demand. Therefore, it is imperative that advanced technologies, including **artificial photosynthesis, satellite solar power, nuclear fusion,** and **geoengineering strategies** be developed now,[3] so that the second and subsequent "runners" have the necessary tools to do their jobs.

References

1. Pacala, S. and R. Socolow, "Stabilization wedges: Solving the climate problem for the next 50 years with current technologies," *Science*, 305, 968 (2004), 13 August.
2. O'Neill, B. C. and M. Oppenheimer, "Dangerous climate impacts and the Kyoto Protocol," *Science*, 296, 1971 (2002).
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Energy storage, H_2 safety, infrastructure
PV production cost

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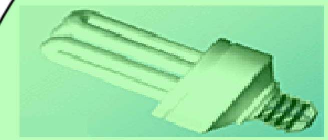

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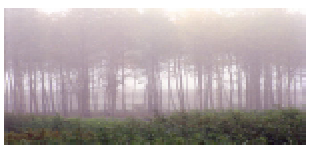
Weak incentives, urban design, lifestyle changes

Efficiency = 4 wedges

Forests & Soils



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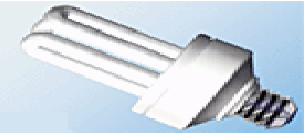

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Weak incentives, urban design, lifestyle changes

Renewables = 4 wedges

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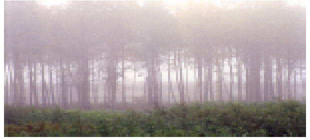

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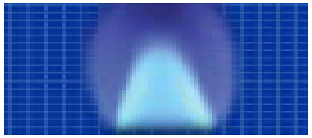

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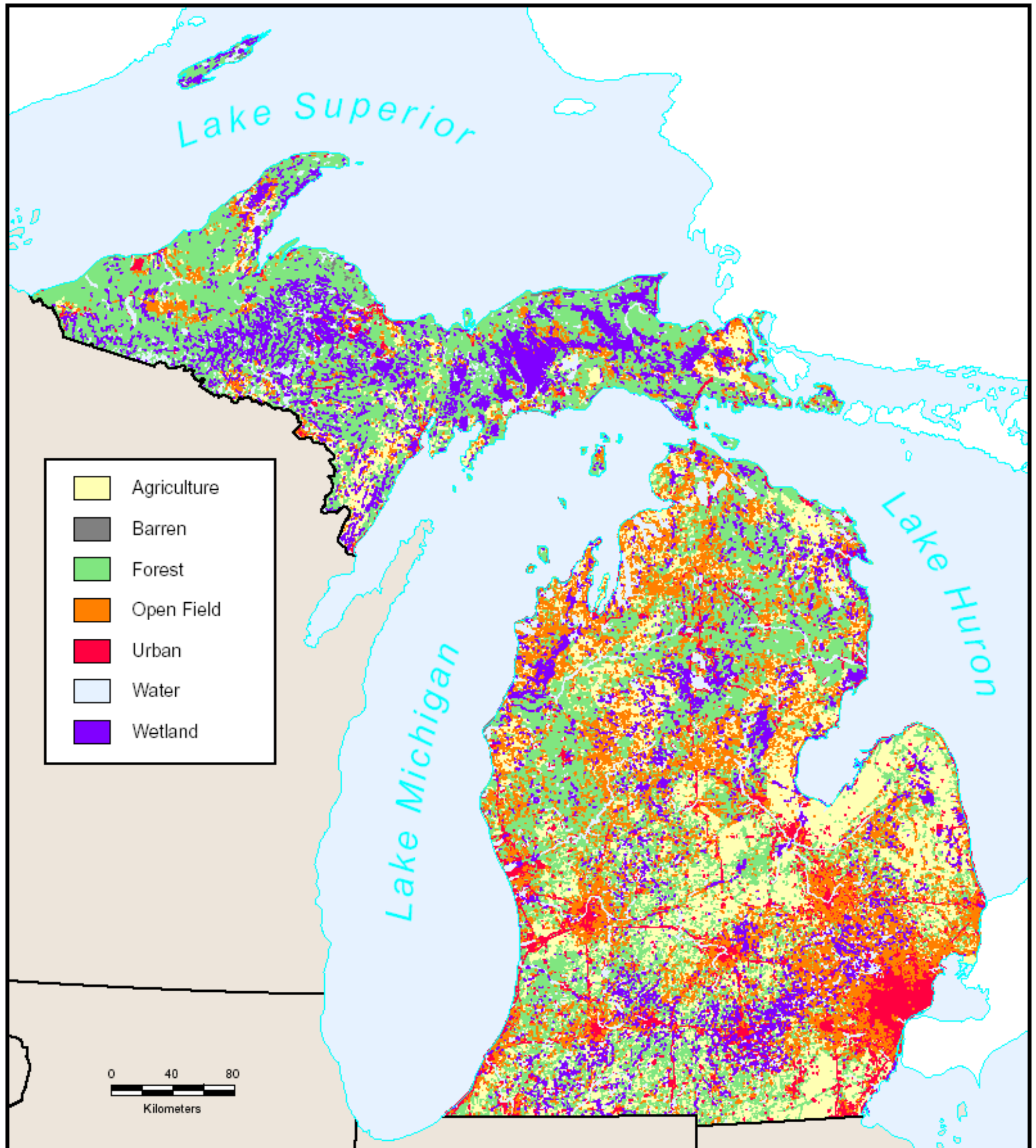
Life cycle energy analysis of renewable energy

		Net Energy Ratio	Carbon Intensity ($g\ CO_2$ eqv./kWh)
	**Wind**	30 – 60	10 – 16
	**Hydropower**	30	26
	**Willow Biomass**	9 – 13	39 – 52
	**BIPV**	3 – 6	44 - 71
	**U.S. Grid**	0.3	990

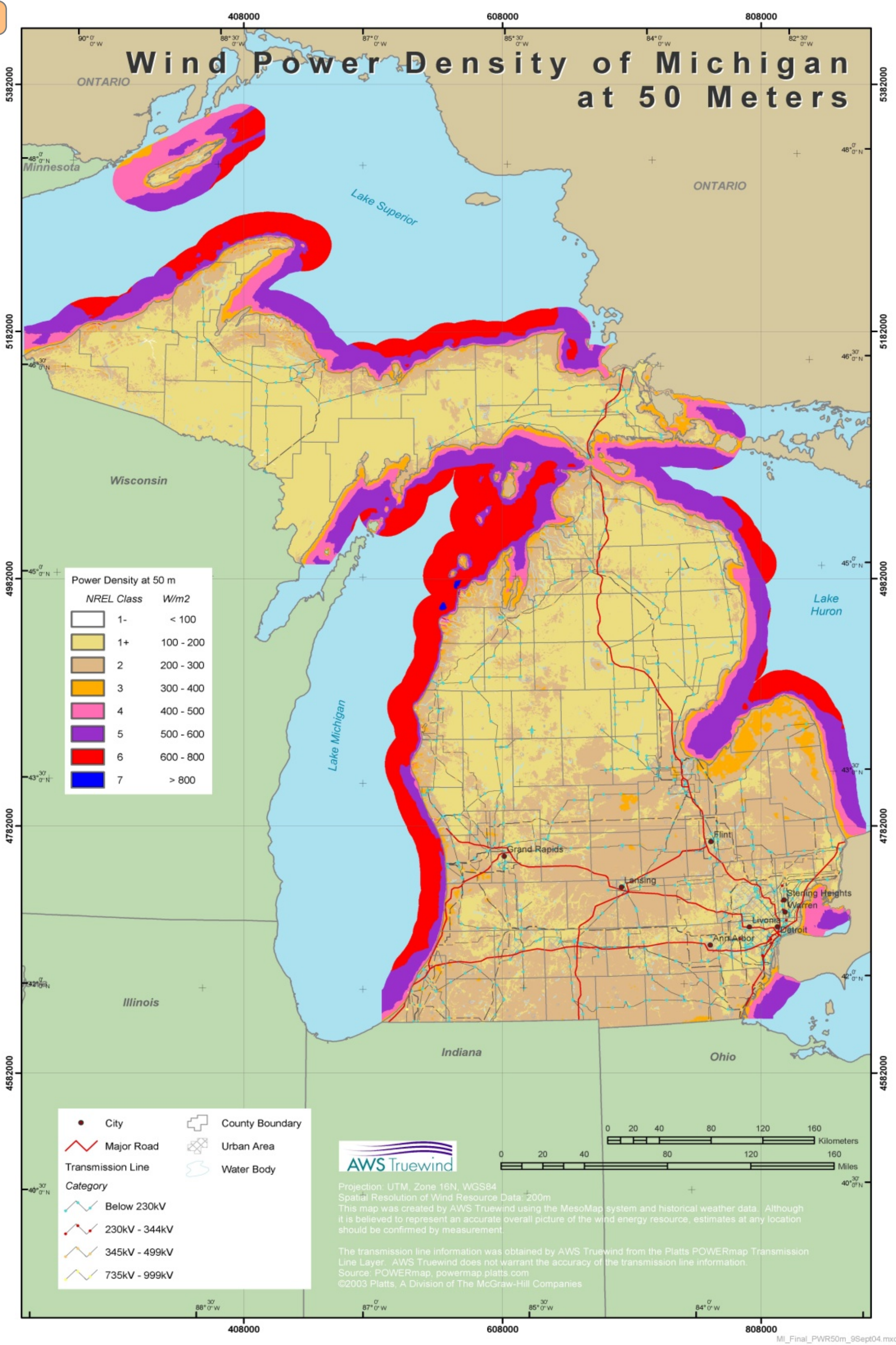
LAND AREA REQUIREMENTS
Electricity consumption in MI = 103 million MWh

980,000 ha
wind farm area
(class 4 wind)

5.7 million ha
willow plantations



130,000 ha
BIPV



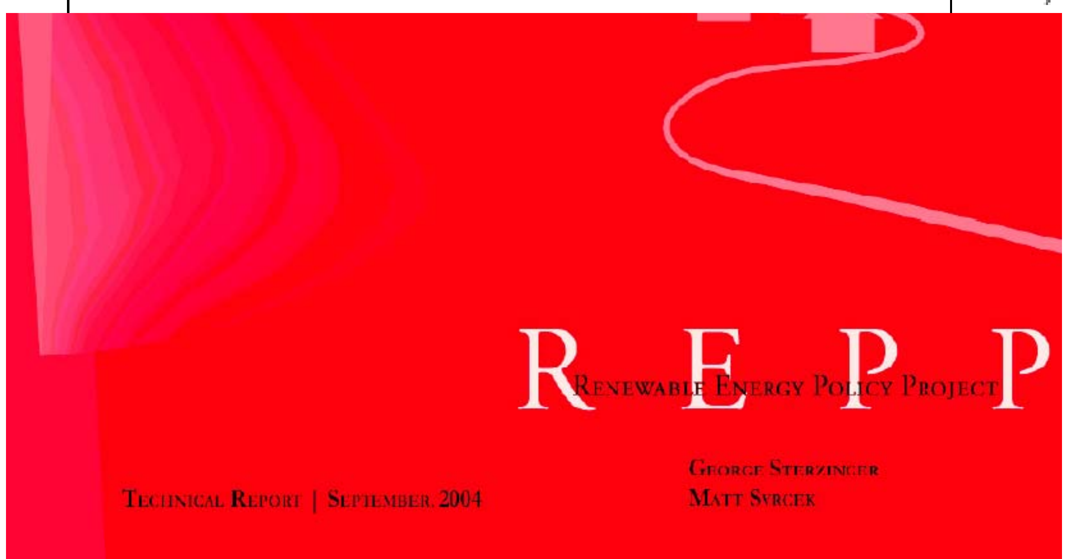
Wind in MI

onshore 16,560 MW est. cap.
≈3.0 MW installed

offshore 44,288 MW est. cap.
0 MW installed

Employment at Potential Active Companies, Investment and Job Creation Potential
Top 20 States Ranked by Average Investment

State	**Employees at Potential Companies**	Rotor	Nacelle and Controls	Gearbox & Drive Train	Generator & Power Electronics	Tower	**Number of New FTE Jobs**	**Average Investment ($ Billions)**
California	**102,255**	25226	52490	1380	14889	8270	**12,717**	**4.24**
Ohio	**80,511**	30578	33367	6360	3372	6834	**11,688**	**3.90**
Texas	**60,229**	15191	28339	1678	3006	12015	**8,943**	**2.98**
$\boxed{\text{Michigan}}$	**66,550**	27719	30241	2466	926	5198	**8,549**	**2.85**



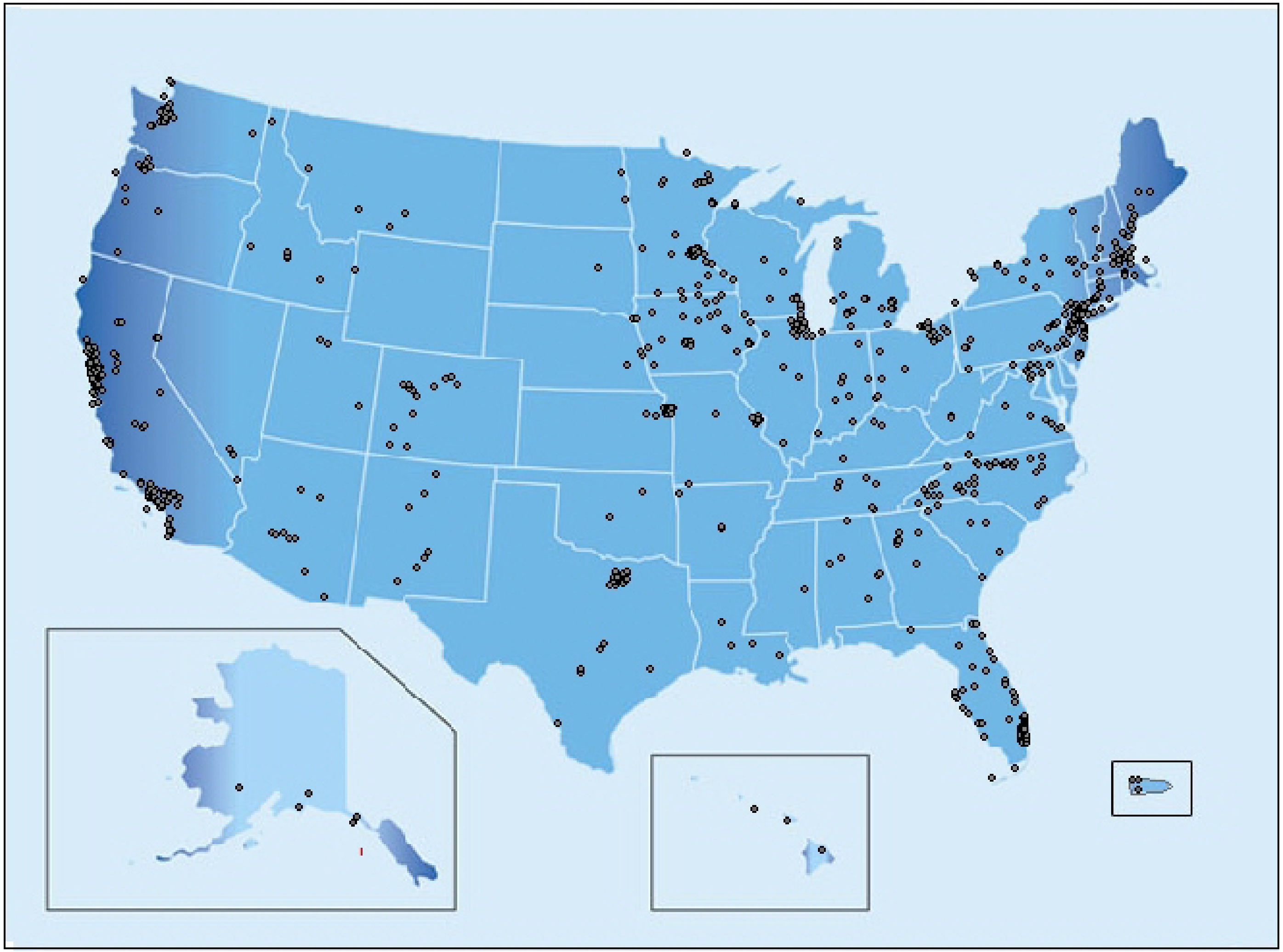
Changing Landscape

- **Sense of the Senate Resolution**

  (to be followed by real legislation?)

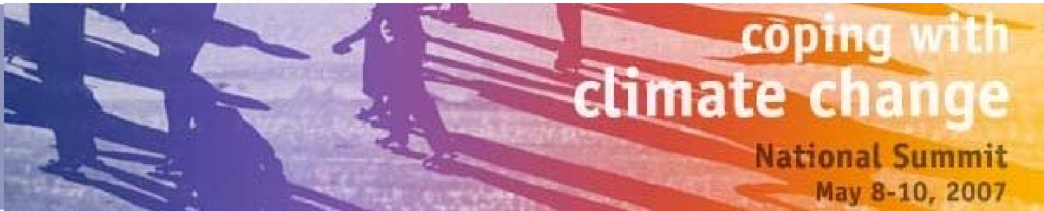
- **Pressure coming from**
  - Cities
  - States
  - Mainstream corporate America
  - Investment
  - International
  - Drumbeat of science
  - New voices: Evangelicals
  - The Nobel prize
  - The election

Mayors' "Kyoto" Agreement: 850 cities as of 7/17/08



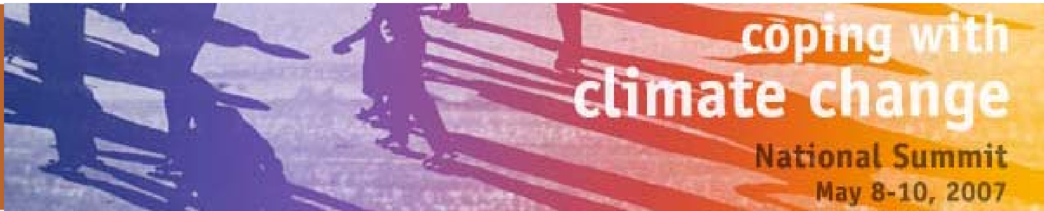
Science Needs:

- **Vulnerability assessments at REGIONAL scales**
- **Breakpoints / thresholds analyses—tipping points?**
- **Preparedness & response to extreme events**
- **Clearing house of 'best practices'—what works?**
- **Build on networks (RISAs, Sea Grant, Ag Extension, LTERS/NEON, etc.)**
- **There are devils in the details....study interactions!**
- **A research strategy with priorities to get the answers that we need in a timely fashion**



And, look at interactions across:

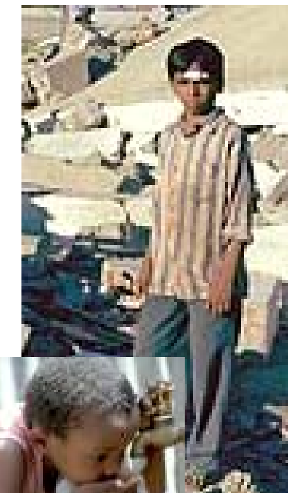
- **Mitigation and Adaptation**
  - e.g., biofuel expansion may greatly increase fertilizer use, deadzones. May increase deforestation.
- **Sectors**
  - e.g., Water & Energy. Heavy water uses for coal nuclear, solar thermal & biofuels may compete with agriculture, wetlands, human use
- **Multiple social and environmental stresses**
  - e.g., warmer temps enhance smog formation and make attainment of air quality standards difficult
  - Habitat fragmentation inhibits species migration










The Challenge: Sustainable Management of an Ever-Changing Planet

Some key references:

Confronting Climate Change: Avoiding the Unmanageable and Managing the Unavoidable, United Nations Foundation, February 2007 *http://www.unfoundation.org/SEG/*

"*Climate Change 2007*", Intergovernmental Panel on Climate Change, *http://www.ipcc.ch/*

Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change,2000 *http://www.usgcrp.gov/usgcrp/Library/nationalassessment/overview.htm*